Environmental Aspects of Air Transport

- Future Technologies & Prospects -

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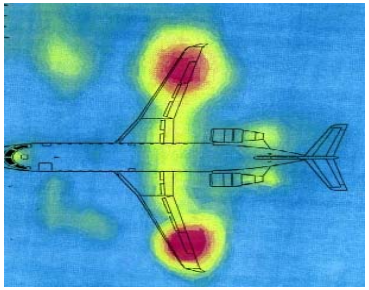
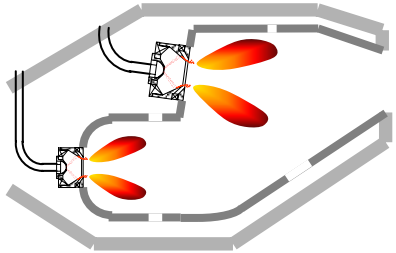
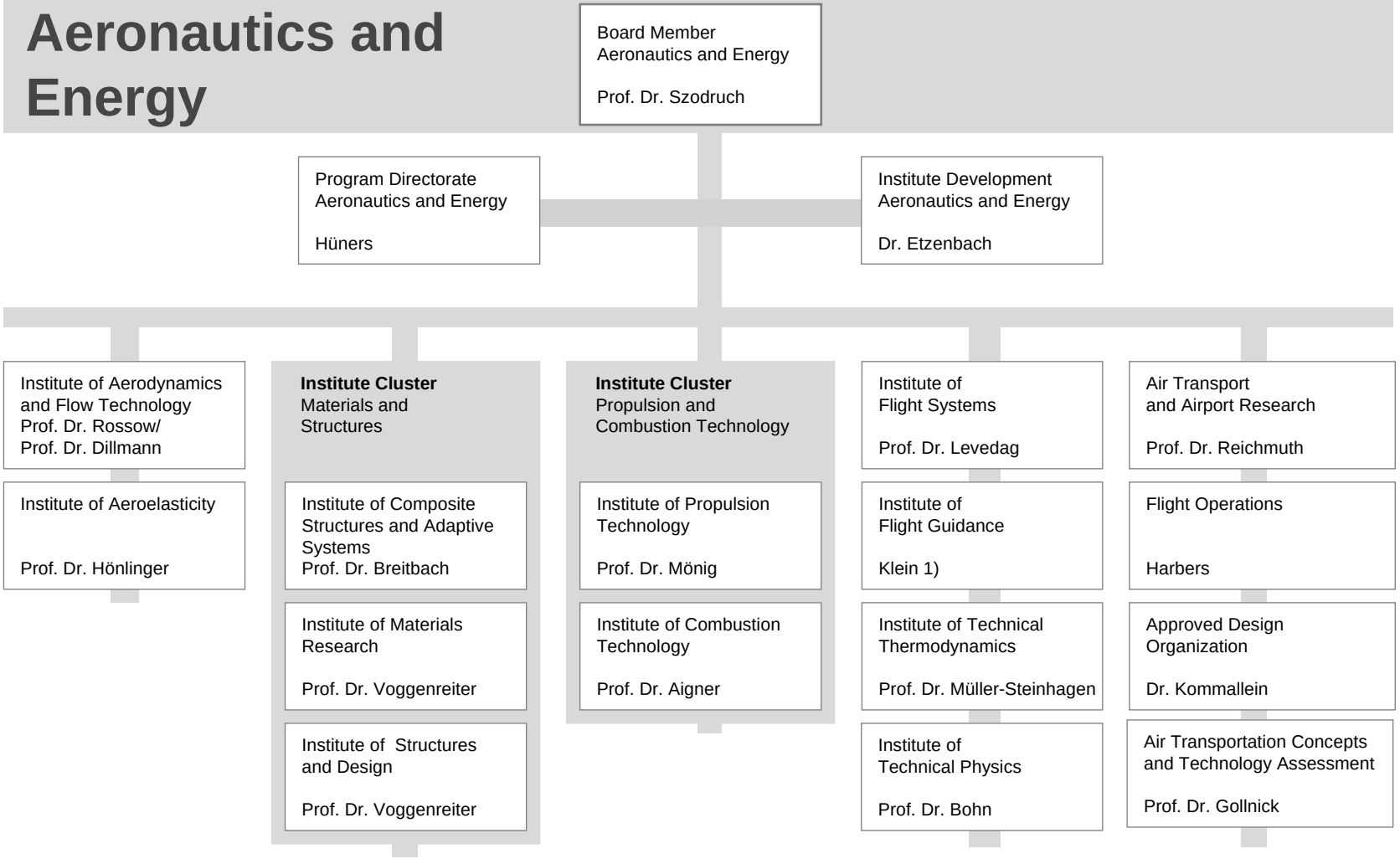




The DLR
German Aerospace Research Center
Space Agency of the Federal Republic of Germany

DLR

Aeronautics and Energy



1) Acting

Sites and employees

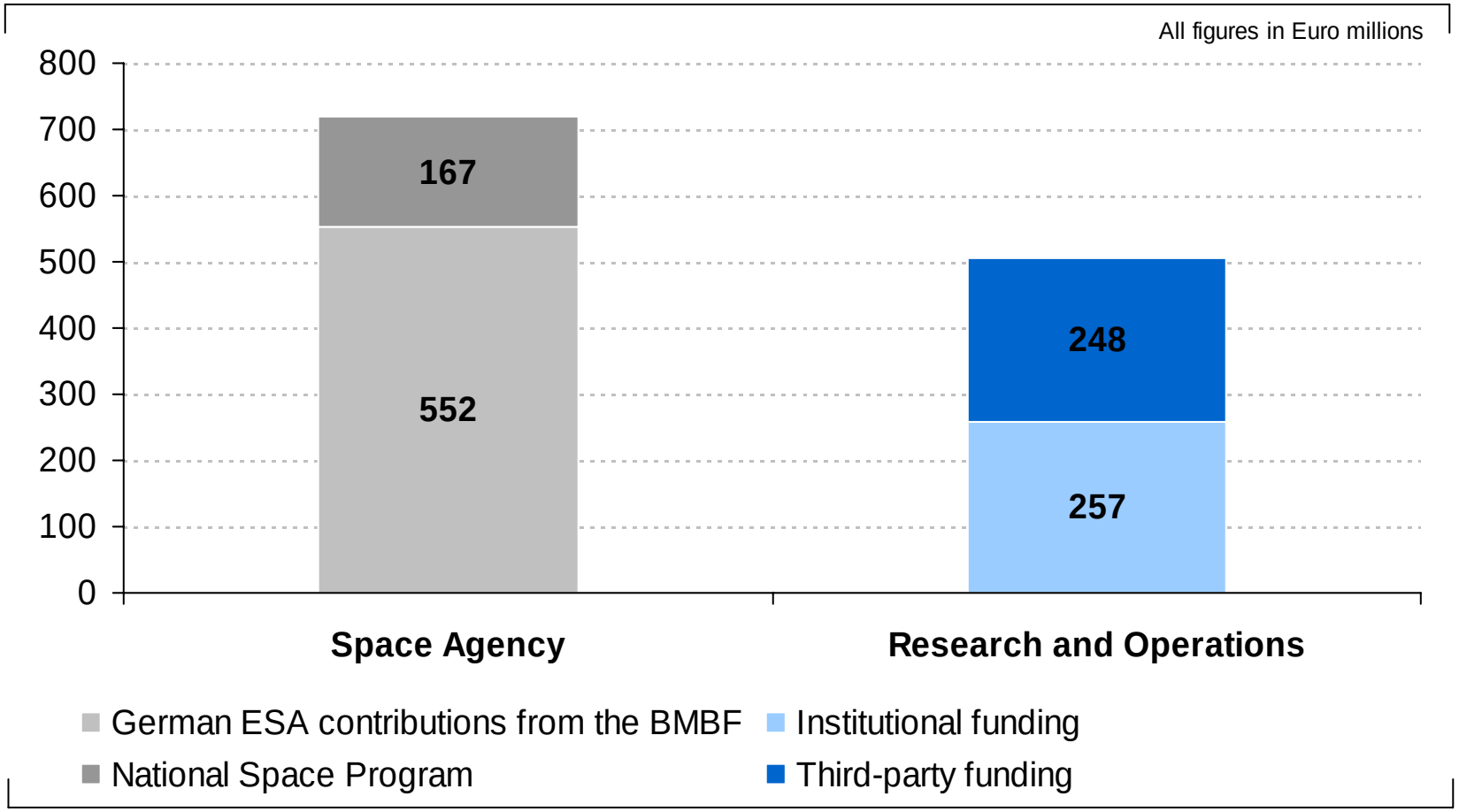
5.100 employees working in 27 research institutes and facilities

- at 9 sites
- in 7 field offices.

Offices in Brussels, Paris and Washington.

Total 2006 budget

€ 1.224 million



Mission

To open up new dimensions for exploring the earth and the universe, for protecting the environment and for promoting mobility, communication and security:

- Research portfolio ranging from basic research to innovative applications and the products of tomorrow
- Operating large-scale research facilities for DLR's own projects and as a service provider for its clients and partners
- Promoting the next generation of scientists
- Advisory services to government

DLR's strategic competencies (1)

Strategic product-related core competencies:

- Design of complex aerospace and transport systems
- Design of complex flight guidance systems
- Improving the performance and environmental friendliness of aerospace engines as well as energy systems
- Remote control and monitoring of aircraft and spacecraft
- Development and operation of remote sensing systems (Data acquisition, transmission, processing and evaluation)
- Remote sensing and telemetry
- Precautionary measures to maintain the health and capability of people in the mobile society

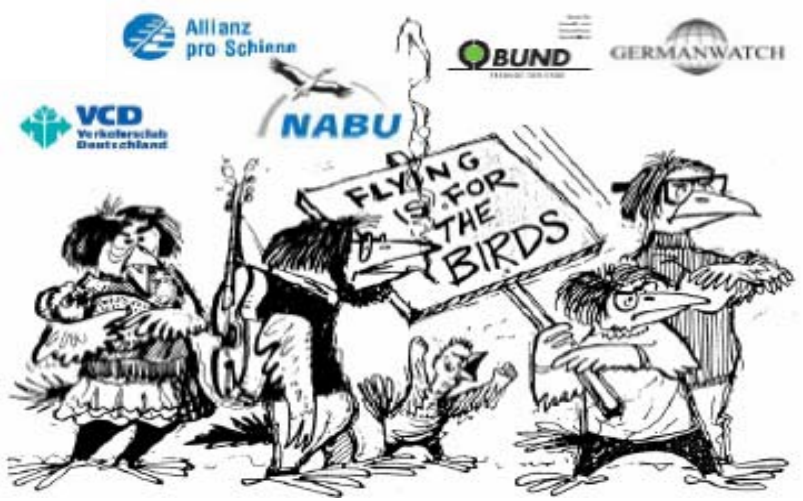
DLR's strategic competencies (2)

Strategic non-product-related core competencies:

- Development of new materials and new production methods
- Numerical simulation and experimental validation
- Management of complex projects and operation of large-scale facilities
- Advisory services to government
- Implementing the German government's integrated space program

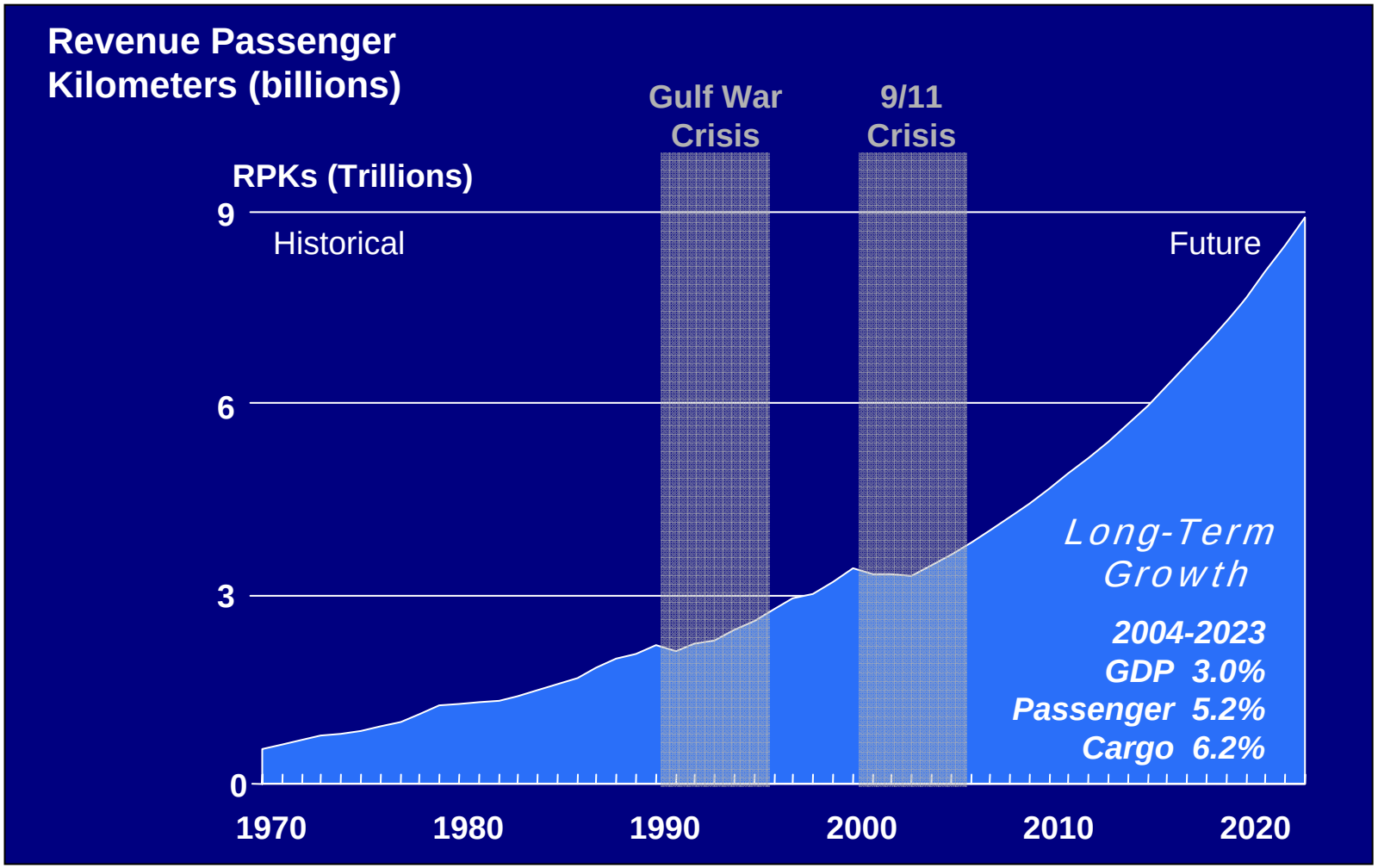
The Problem

The “Anti”-Organisations



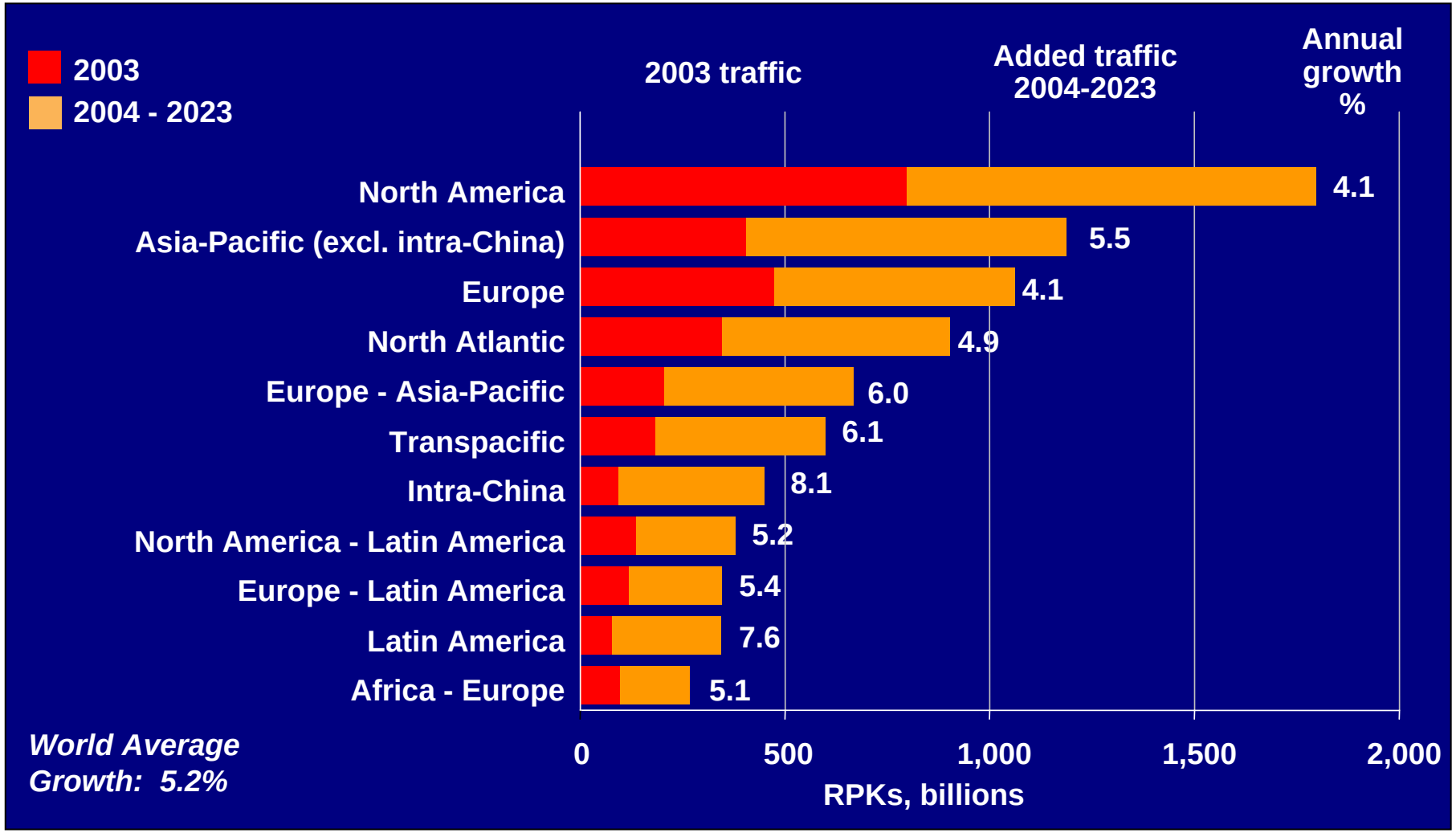
Air Transport in Public Perception …

World Air Travel Forecast



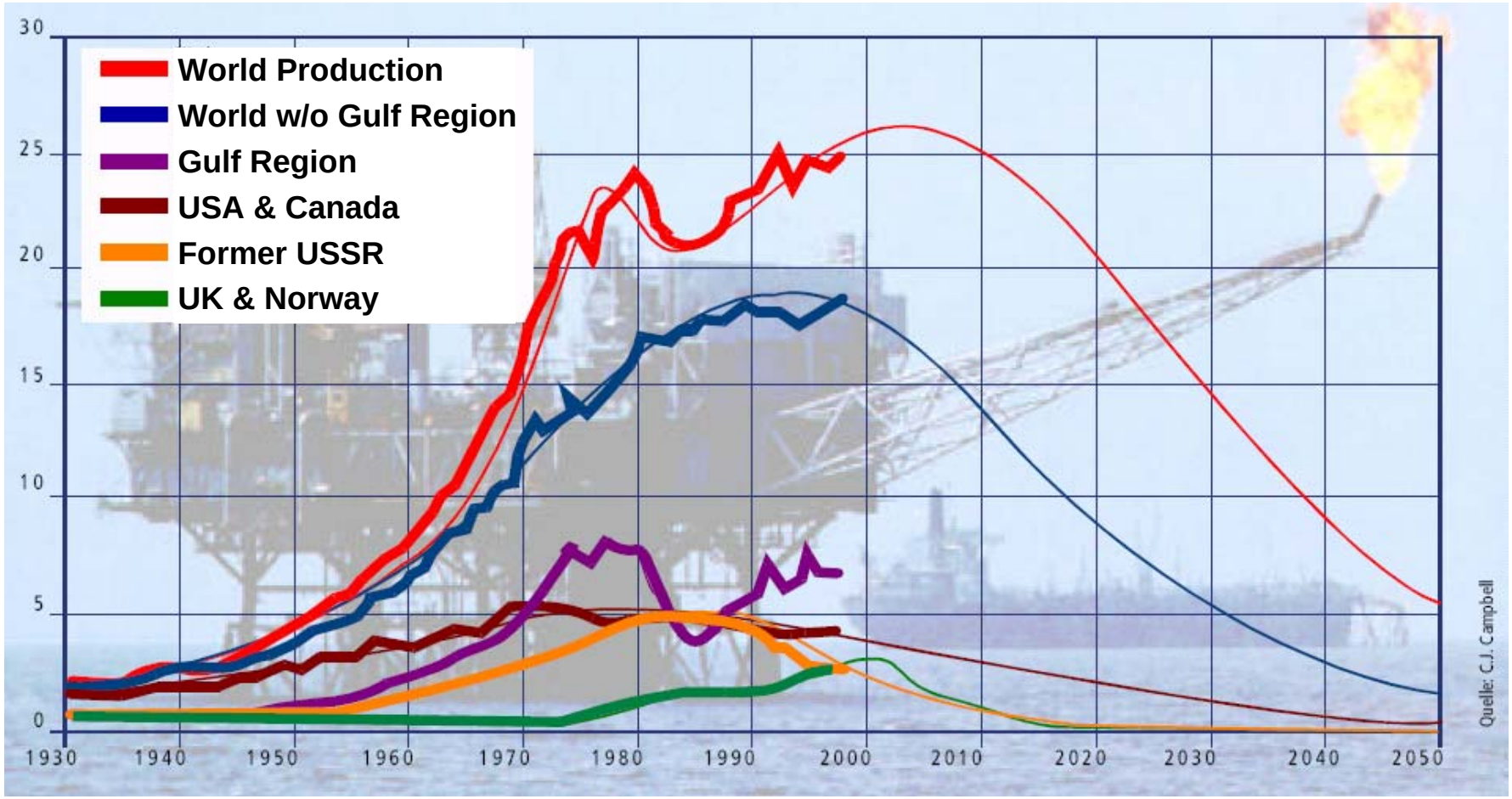
Source: Boeing Market Qutlook 2005

Air Travel Forecast by Region



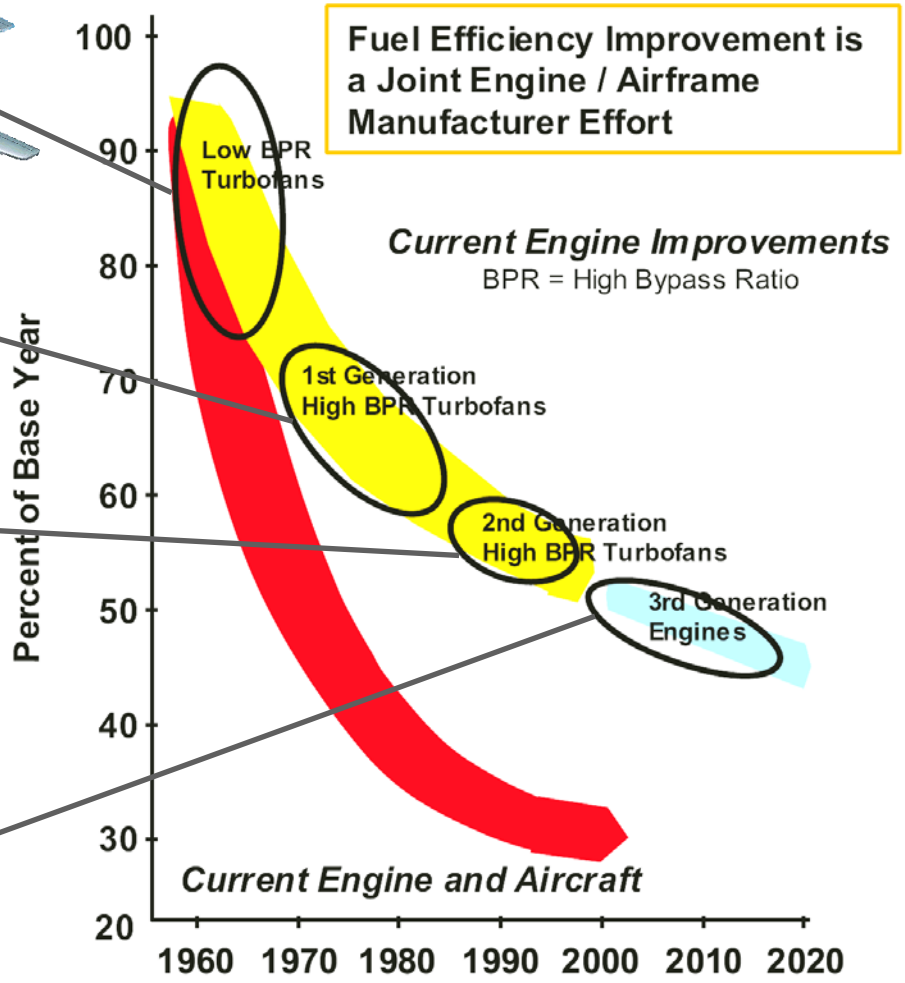
Source: Boeing Market Qutlook 2005

Oil Production Forecast 1930-2050



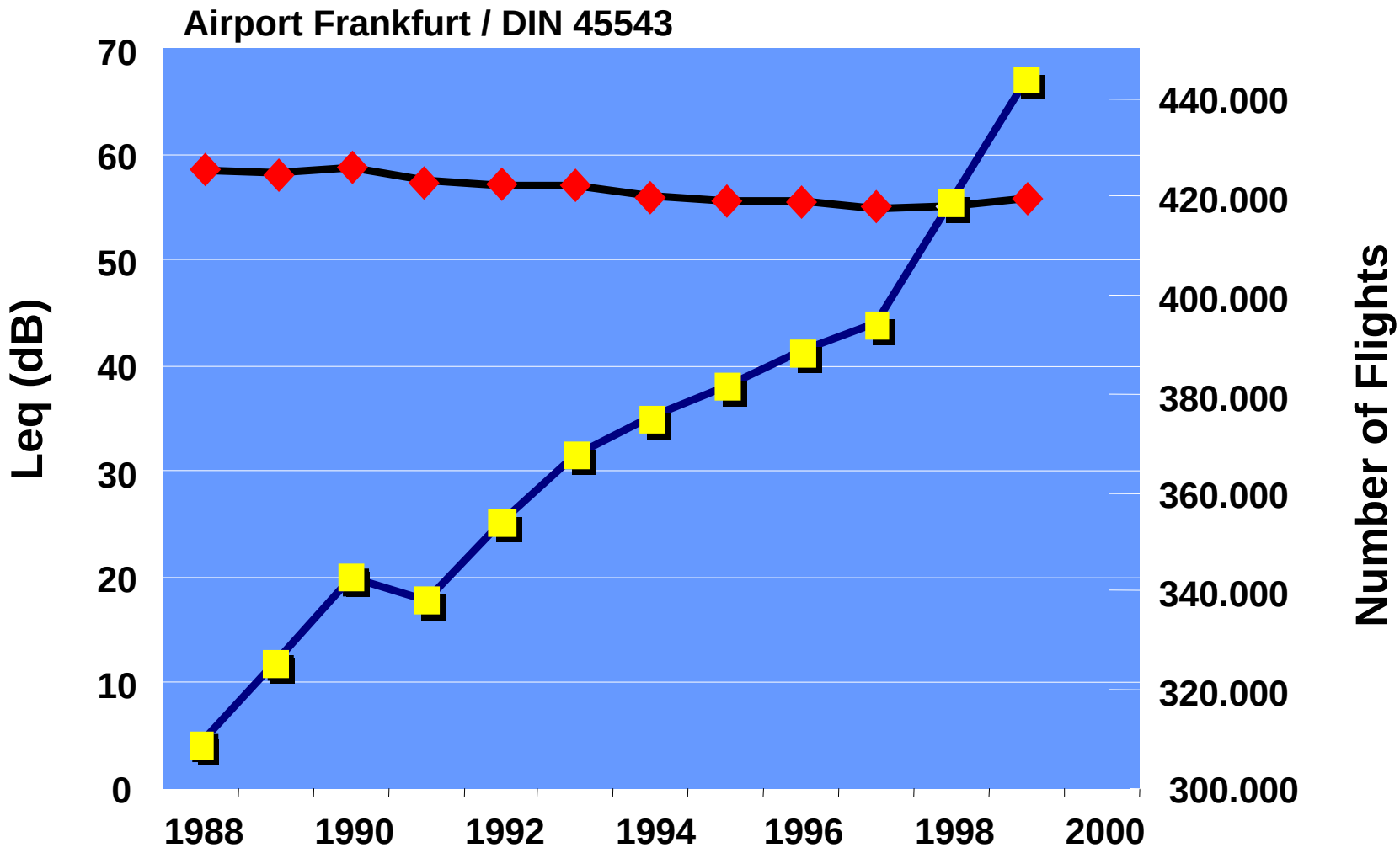
Reduction of Fuel Consumption

Examples:



Source: Boeing

Constant Level of Noise



Source: Dr. Beder Consult

Vision 2020 – Challenges and Goals

- **Quality and Affordability**
  - *Reduced passenger charges*
  - *Increased passenger choice*
  - *Transformed freight operations*
  - *Reduced time to market by 50%*
- **The environment**
  - *Reduction of CO_2 by 50%*
  - *Reduction of NOx by 80%*
  - *Reduce perceived external noise by 50%*
  - *Substantial progress towards 'Green MMD'*
- **Safety**
  - *Reduction of accidents rate by 80%*
  - *Drastic reduction in human error and its consequences*
- **The Efficiency of the Air Transport System**
  - *3X capacity increase*
  - *99% of flights within 15' of schedule*
  - *Less than 15' in airport before short flights*
- **Security**
  - *Airborne - zero hazard from hostile action*
  - *Airport - zero access by unauthorised persons or products*
  - *Air navigation - No misuse. Safe control of hijacked aircraft*

Reference: Year 2000

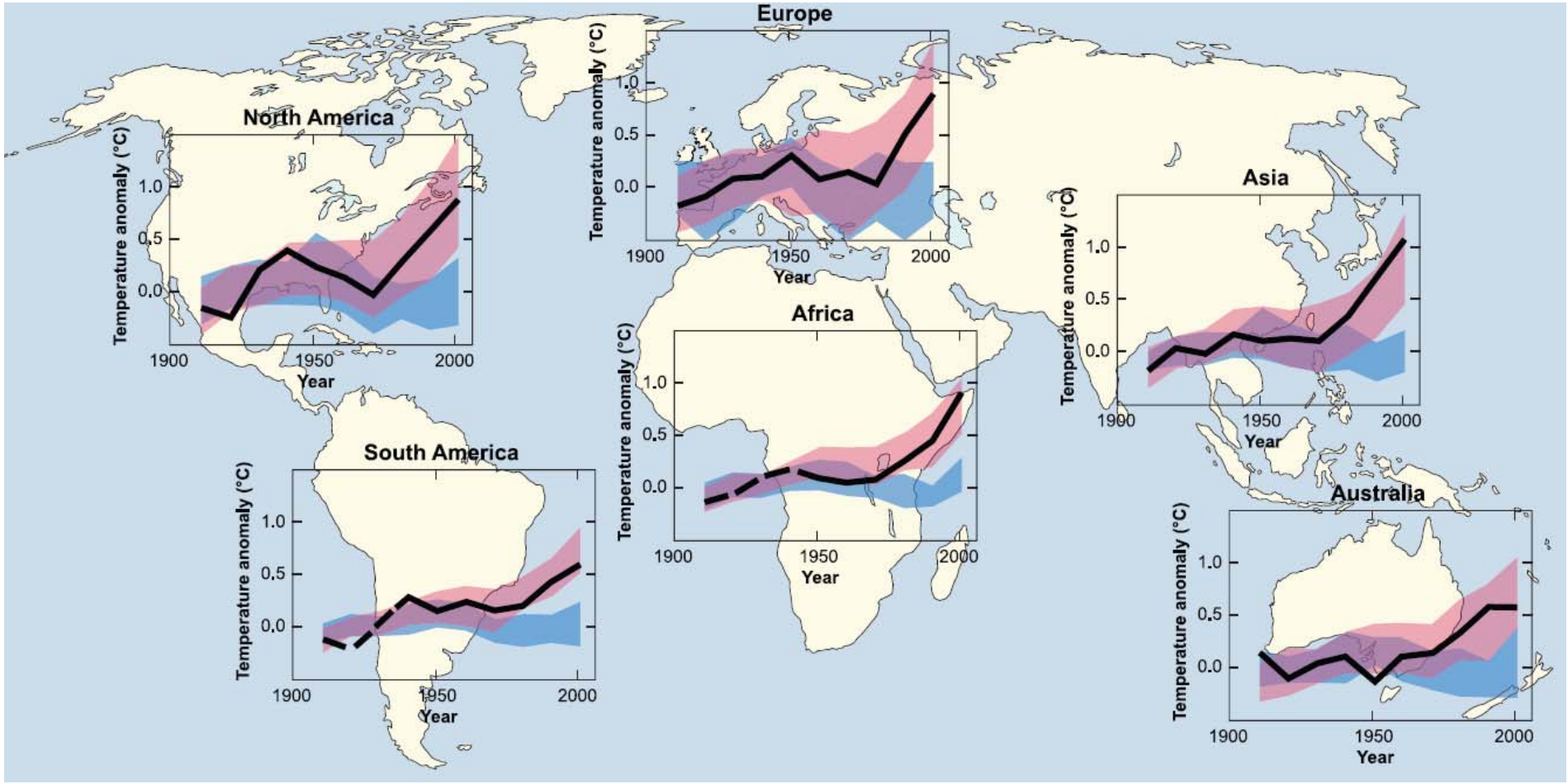
Introduction

Vision 2020 Targets (relating to a/c)

- Reduce CO_2 by 50%
  (20% by engine improvement
  25% by airframe improvement,
  5% by improved operation)
- Reduce NO_x by 80%
- Reduce perceived noise by half
  (equiv. to 10 EPNdB reduction)
- Eliminate noise nuisance outside airport boundaries
- Affordability

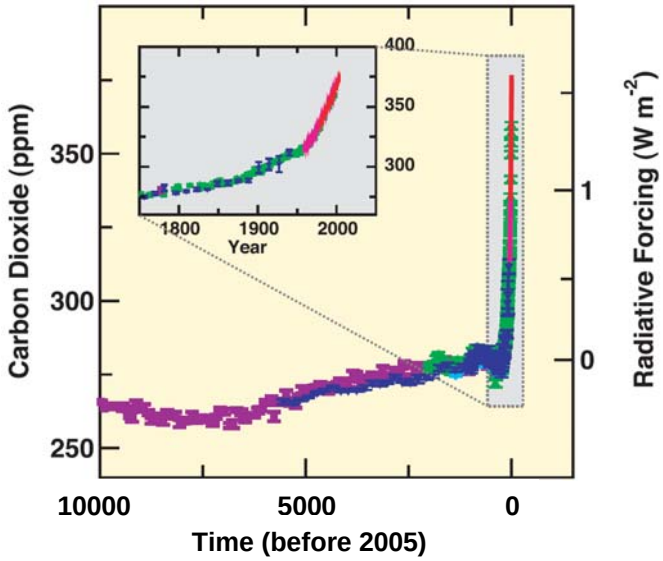
Environmental Impact of Air Transport

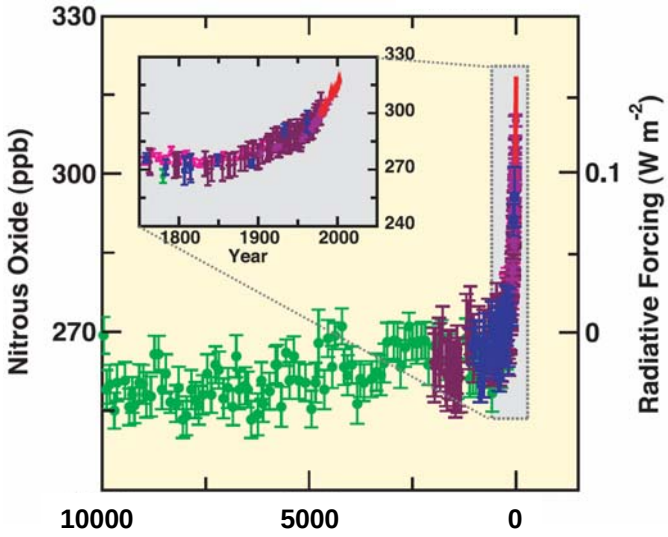
IPCC-Report: Global Warming



Source: IPCC, 2007

Green House Gas Concentrations

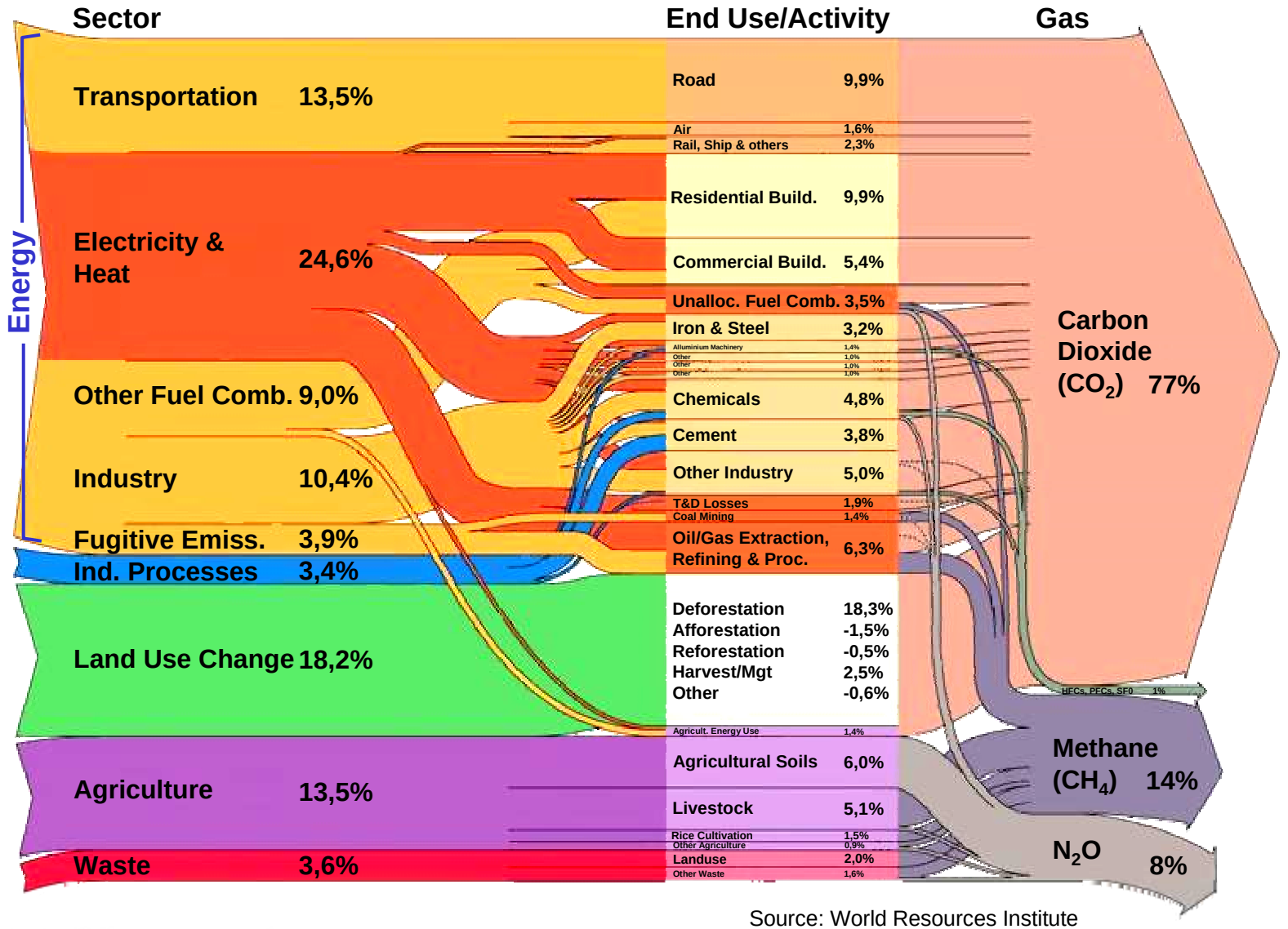




Source: IPCC, 2007

Environmental Impact of Air Transport

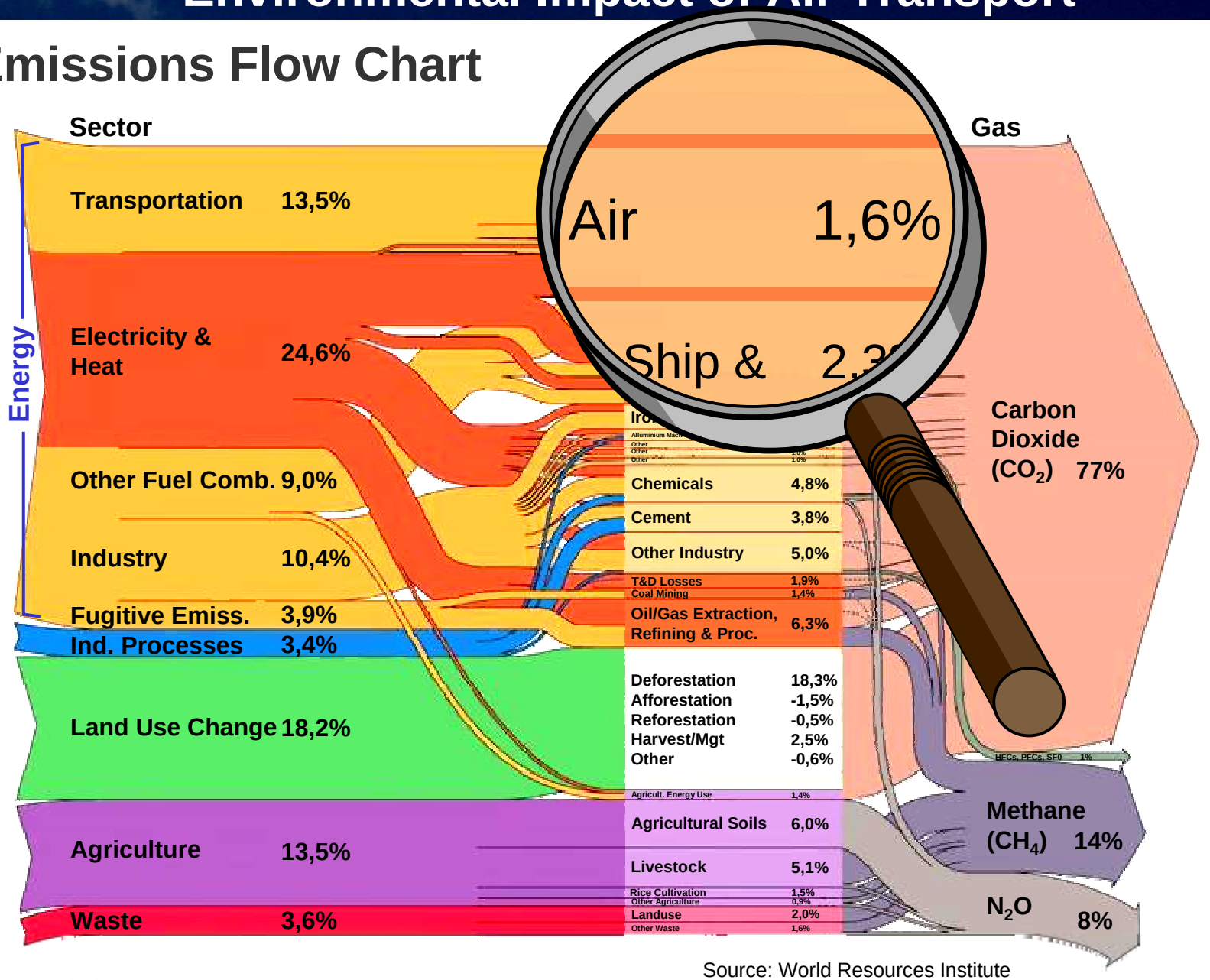
Emissions Flow Chart



Source: World Resources Institute

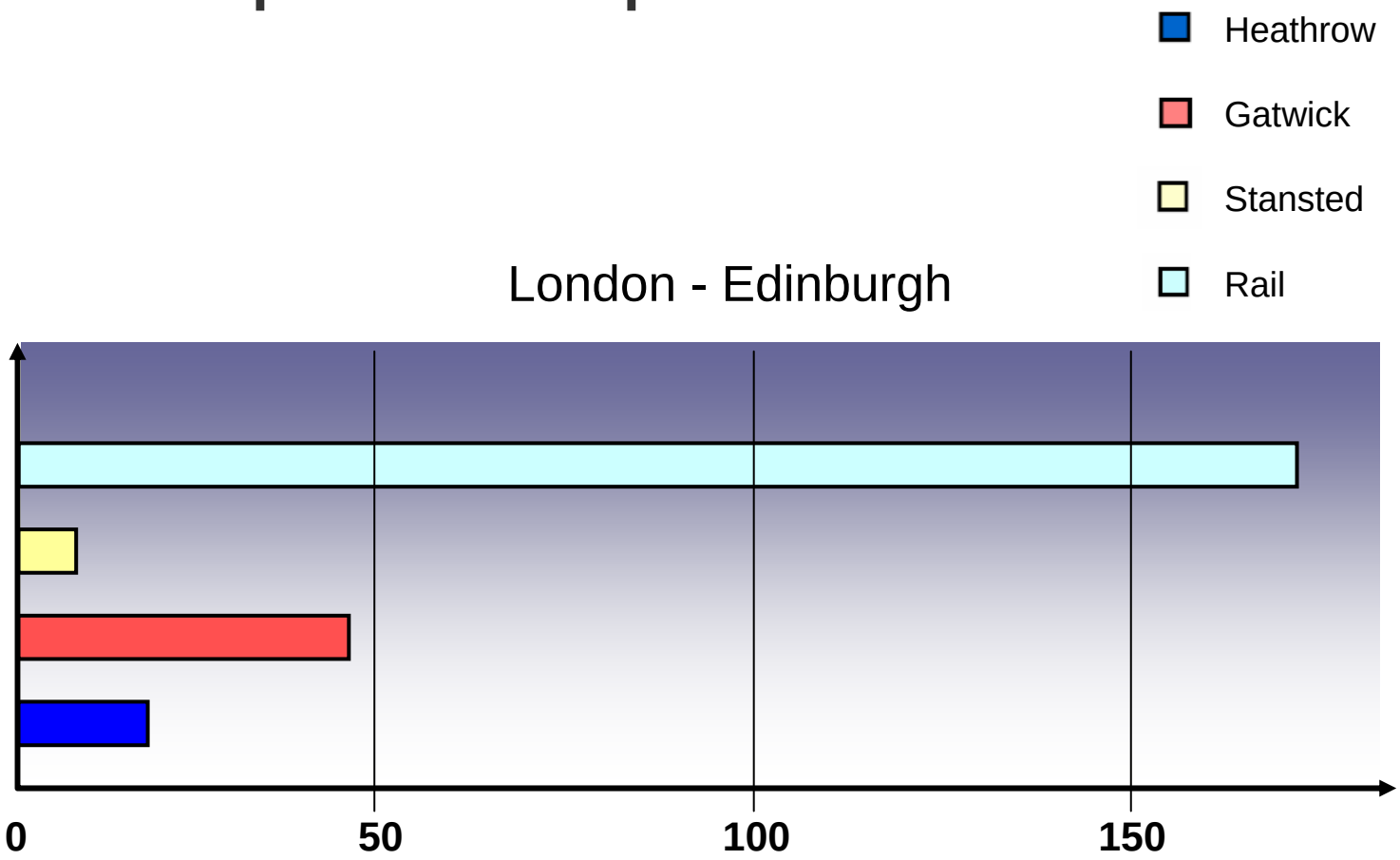
Environmental Impact of Air Transport

Emissions Flow Chart



Source: World Resources Institute

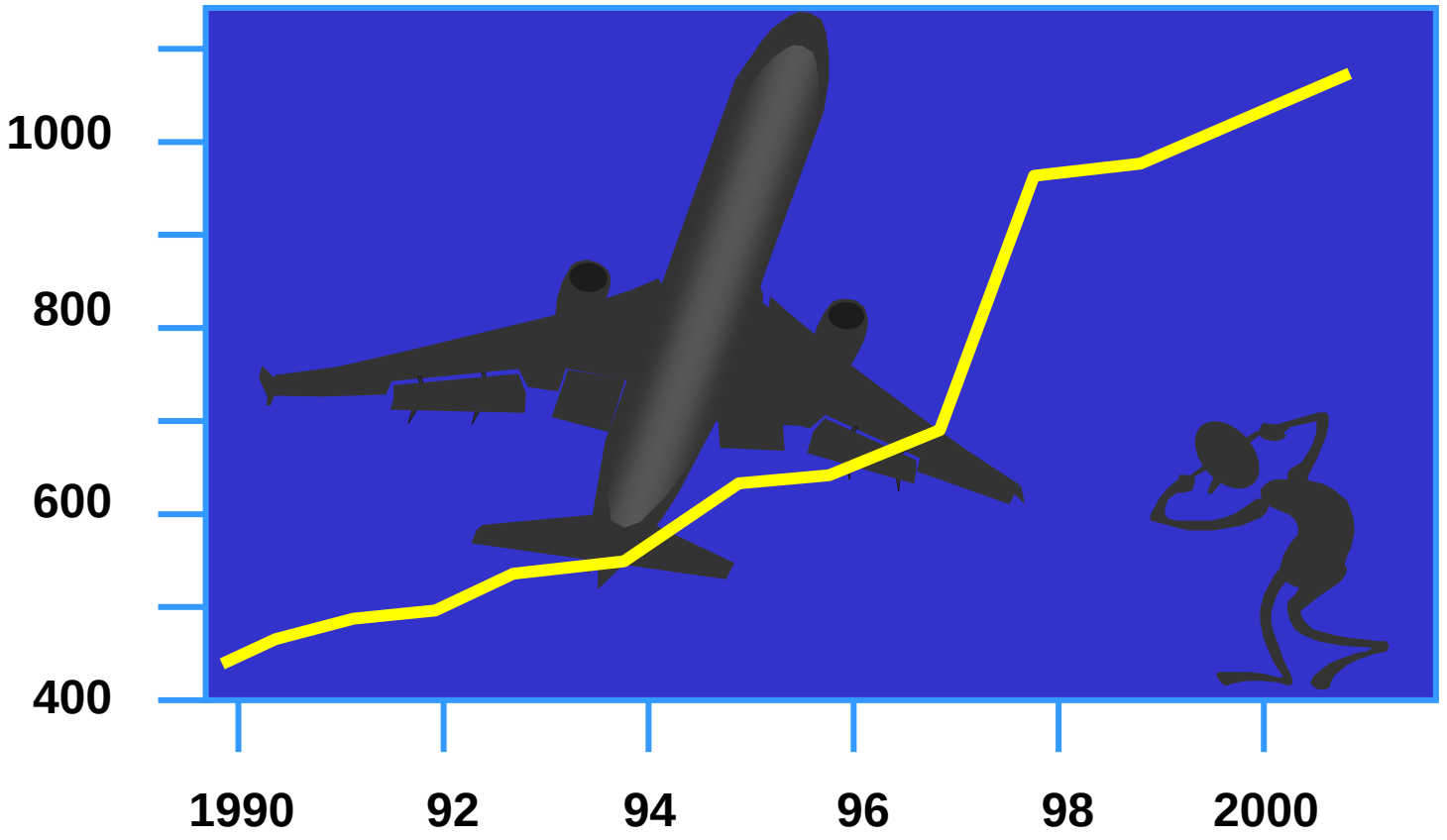
Noise Exposure of Population



Population exposed per passenger journey (average occupancy) 90dB SEL

Source: AEA Techn., CAA, 2001

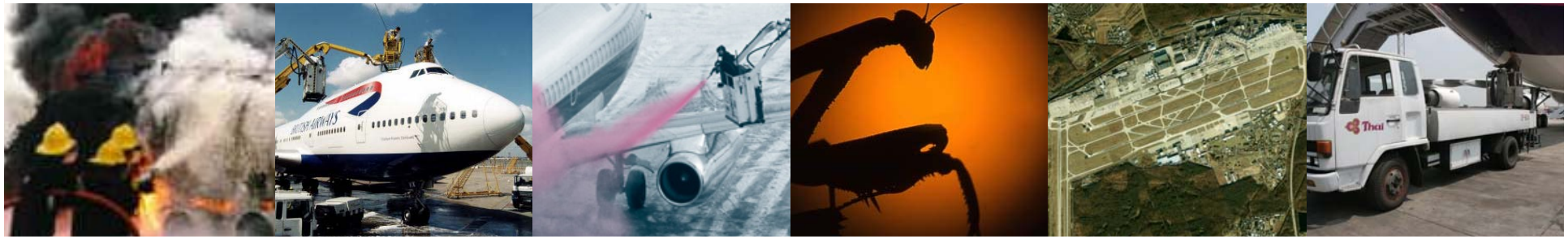
Number of Airports with Noise Restrictions



Source: NASA Aero Blueprint 2002

Other Potential Effects

- Fuel Spills (Kerosene, fire fighting foam)
- Releases during terminal operation, cleaning and maintenance (e.g. Chlor-Fluor-Carbon)
- De-Icing Liquids (e.g. Glycol)
- Herbicides, pesticides and insecticides
- Habitat disruption from land-take and fragmentation
- Waste generation and disposal
- Effects from oil extraction, transportation and processing



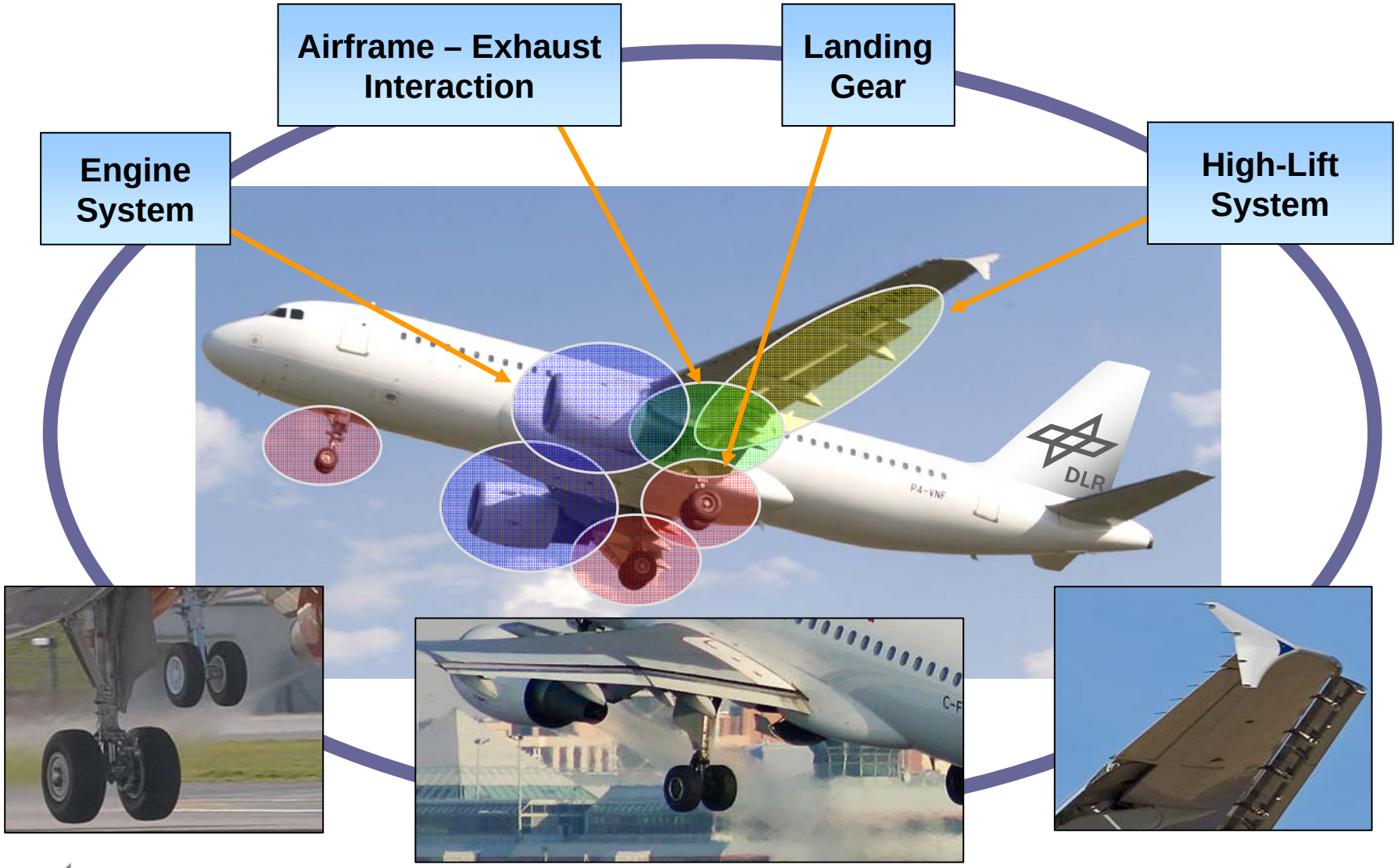
Conclusion

- Global warming is a proven fact
- Green house gas contribution of air transport is relatively small – however, to be taken into consideration are:
  - Longevity of gases at altitude
  - Specific impact of green house gases at altitude
  - Tripled air traffic until 2020
- Future public acceptance of air traffic dominated by noise nuisance

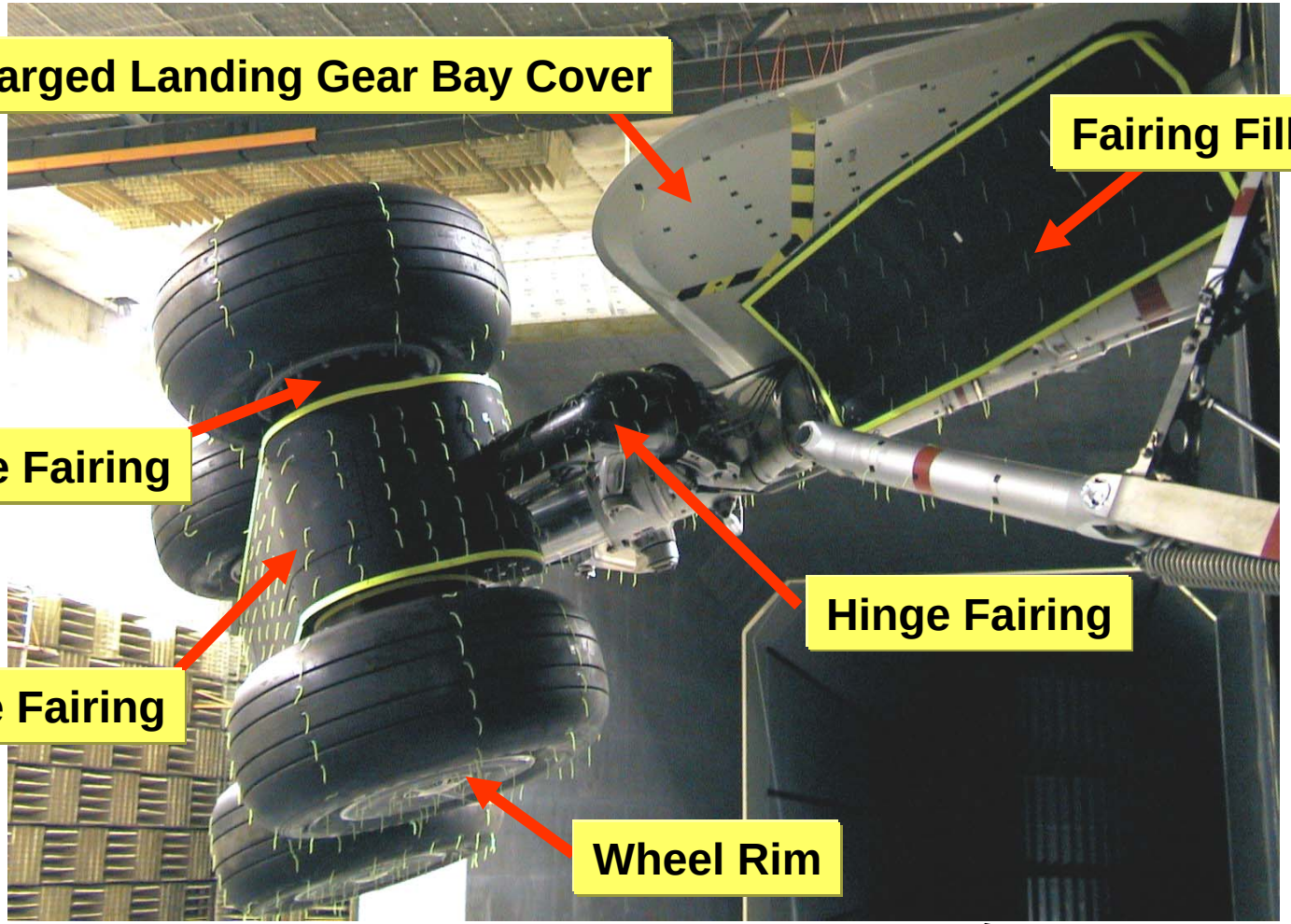
Noise & emission reduction of paramount importance

Noise Reduction

Main Noise Sources

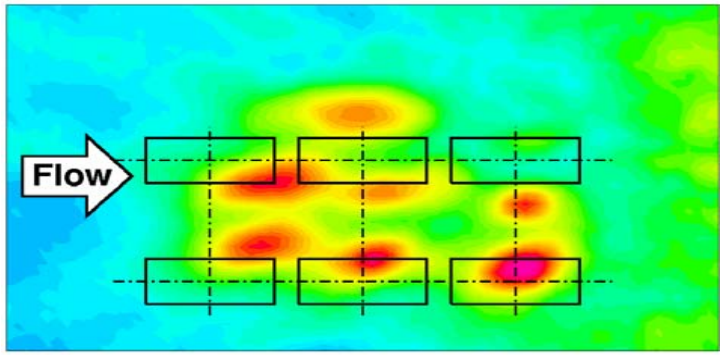


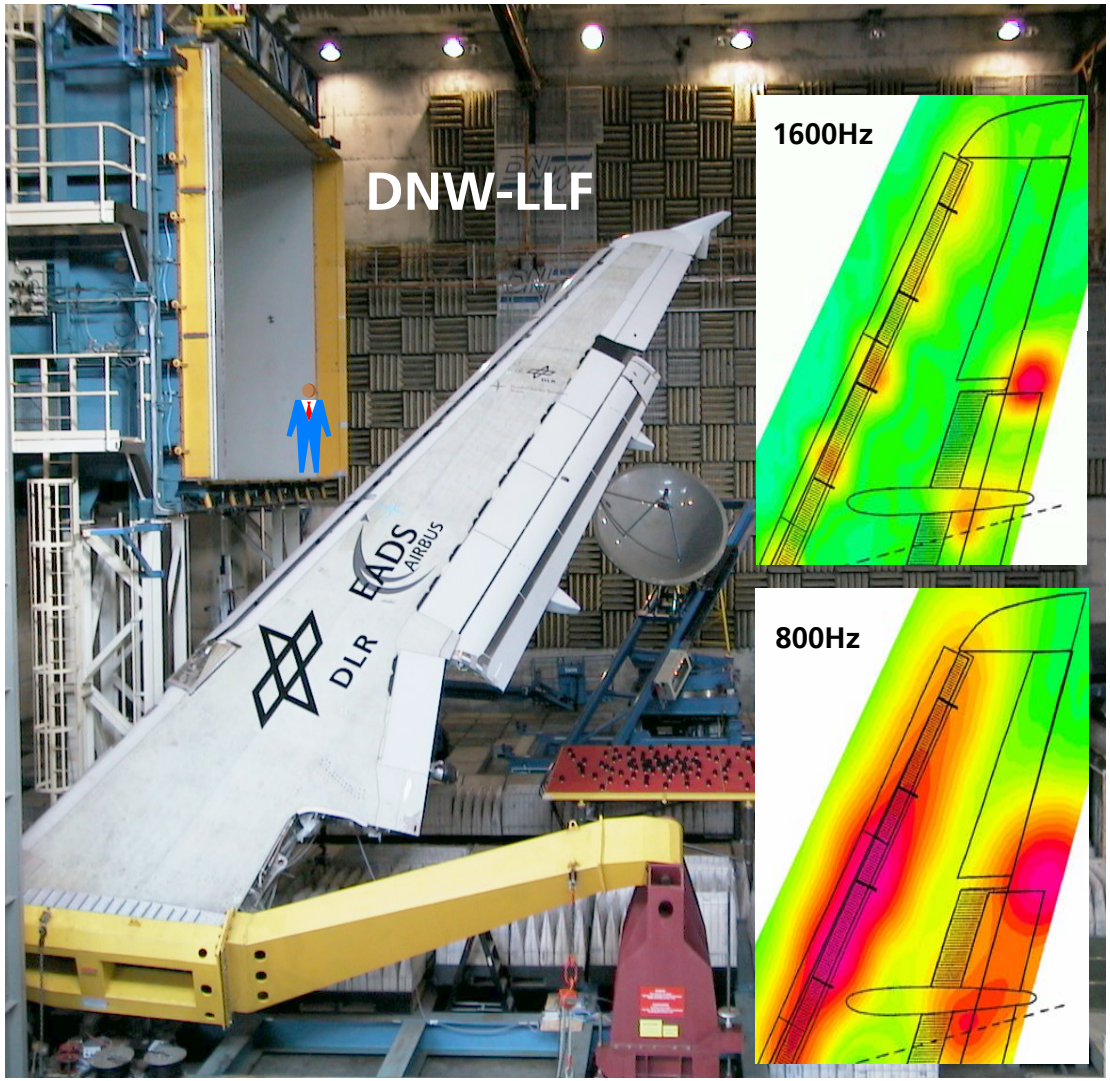
Noise-Optimized Landing Gear



max. -5 dB through realistic partial fairing

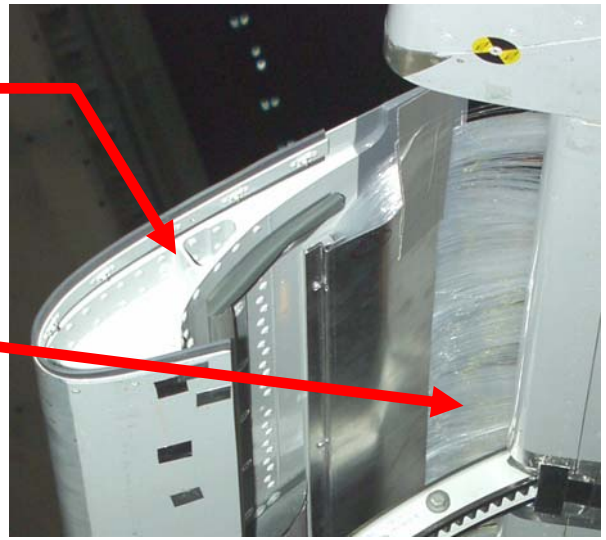
Full Scale Investigation of Noise Sources



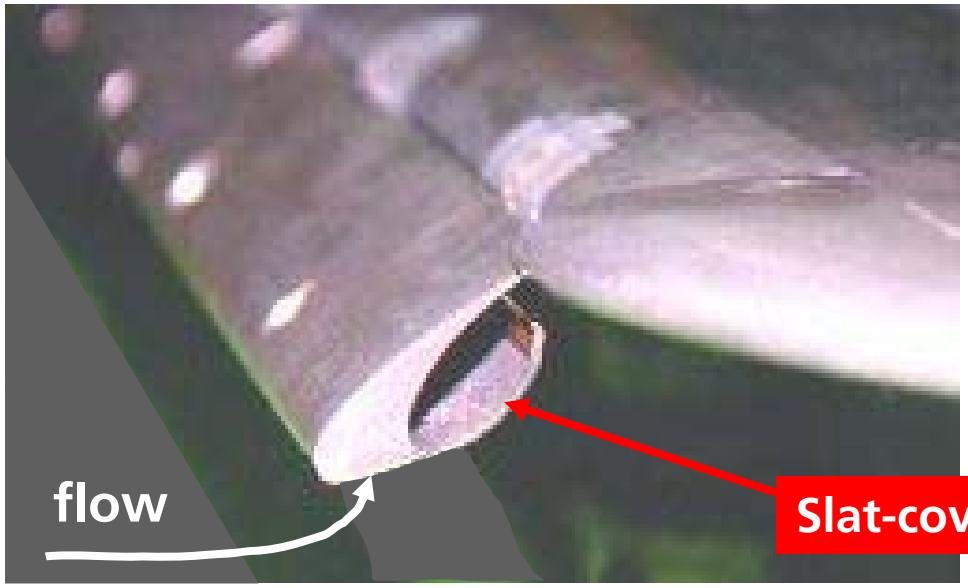


Noise Reduction Potential at Slat and Flap

- -2 dB by fillets in cavities
- -5 dB with brushes on slat/flap trailing edge



Slat Noise at High-Lift



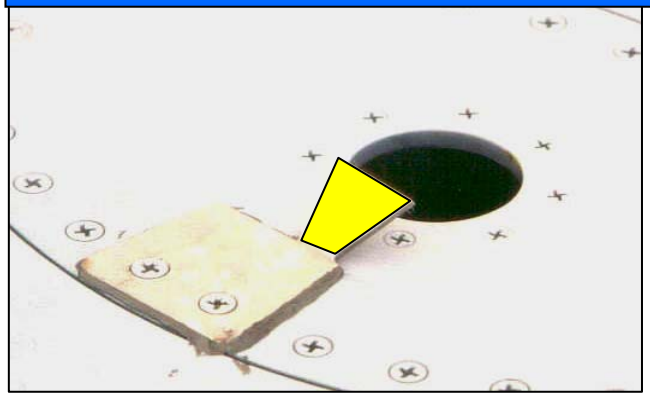
Slat-cove-cover

-3 dB far field noise reduction

A319 Flyover measurements DLH / DLR

- Transfer of wind tunnel based expertise into real flight situation
- Reduction of excess noise from „acoustically detrimental“ details

Vortex generators to eliminate hole tones



Sealing of slat track cutouts

2 dB(A) bbn reduction

Foam filler at flap side edge

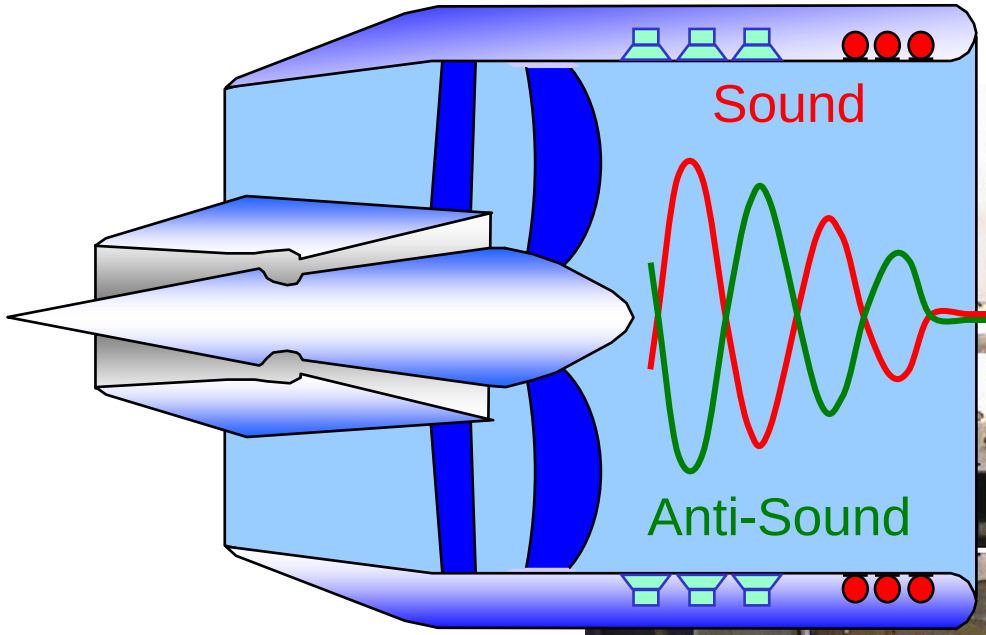
1-2 dB(A) bbn reduction

A319 Flight Test DLR/LH (Autumn 2001)

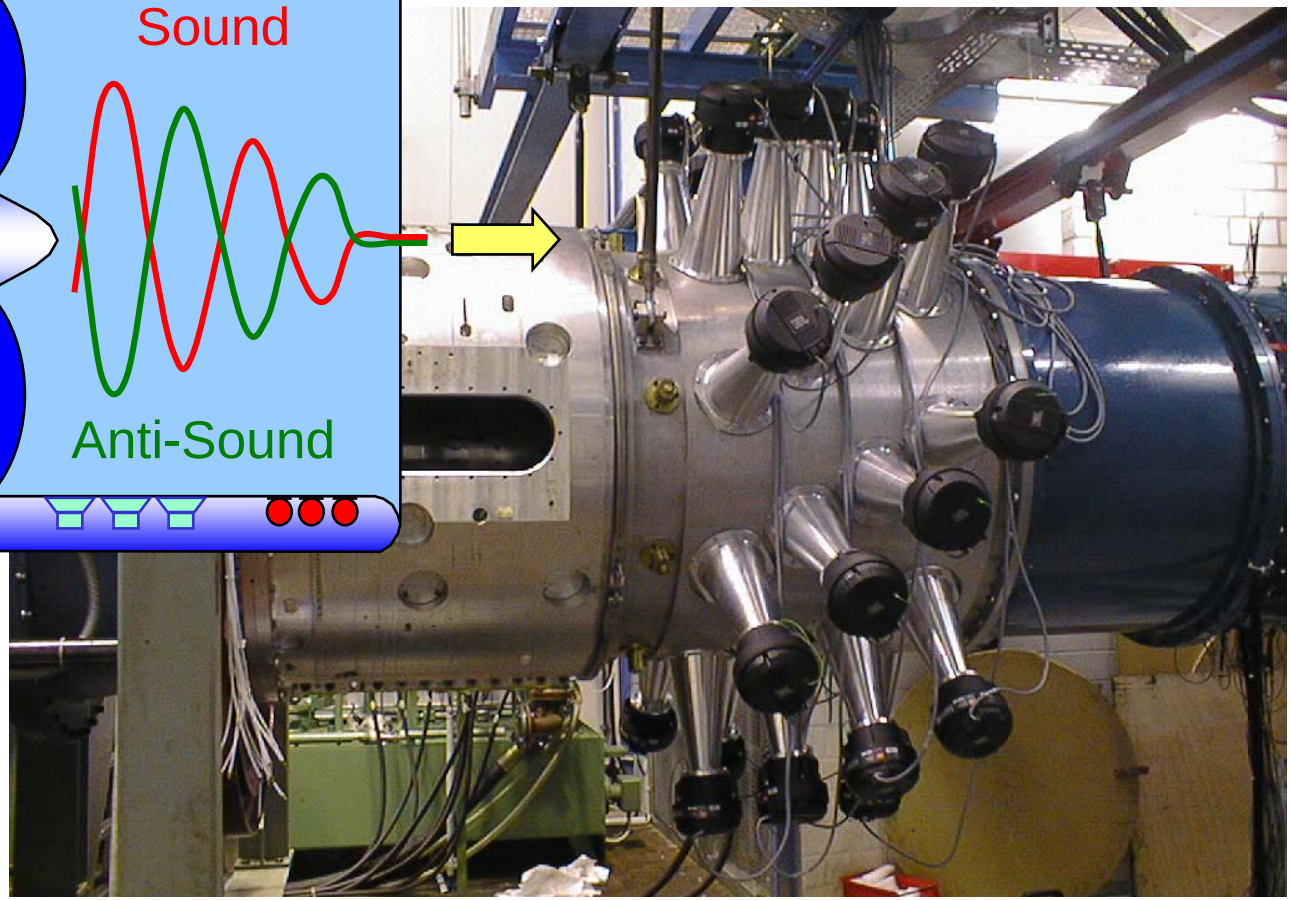
-1 to -3 dB far field noise reduction: short term

Boeing 787 Roll-Out (Summer 2007)

Active Noise Control for Aeroengines

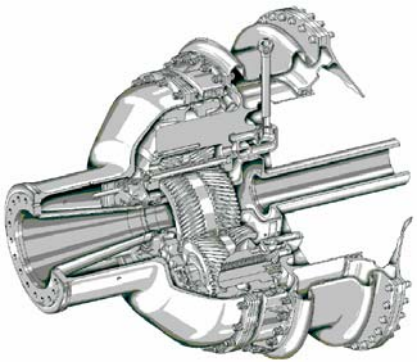


Principle



Experimental Rig at DLR Cologne

Low-Speed Geared (low noise) Fan

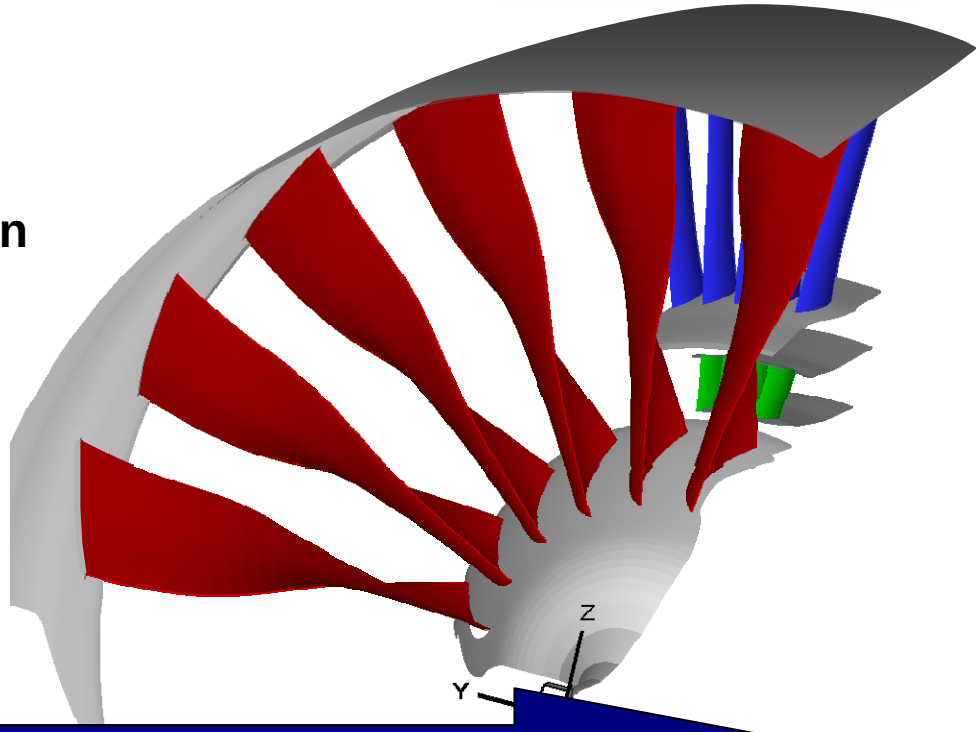


Average flow Mach number at blade tips

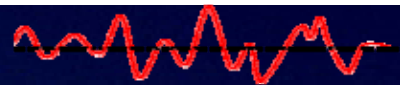
Today´s fans (BPR ~ 6): $Ma_{rel} \approx 1,5$

Geared fan (BPR $\geq$ 12): $Ma_{rel} < 1,0$

Demonstration with a model fan in EU-Project SILENCE(R)



up to -6 dB noise reduction at BPR 12



Potential for Noise Reduction

- **Short Term (3-5 years): 2-3 dB**
  - Modification of airframe and landing gear
  - Chevron nozzle
- **Medium Term (5-10 years): 5-6 dB**
  - Noise-reduced high-lift devices and landing gear
  - Aero-engine design-to-noise
  - Active/passive noise reduction
  - Noise-optimized flight patterns
- **Long Term (15-20 years): 10-12 dB**
  - Aircraft design-to-noise
  - Geared fan with high bypass ratio (>14), engine integration
  - Low-noise core engine
  - Noise-optimized ATM

Emission Reduction

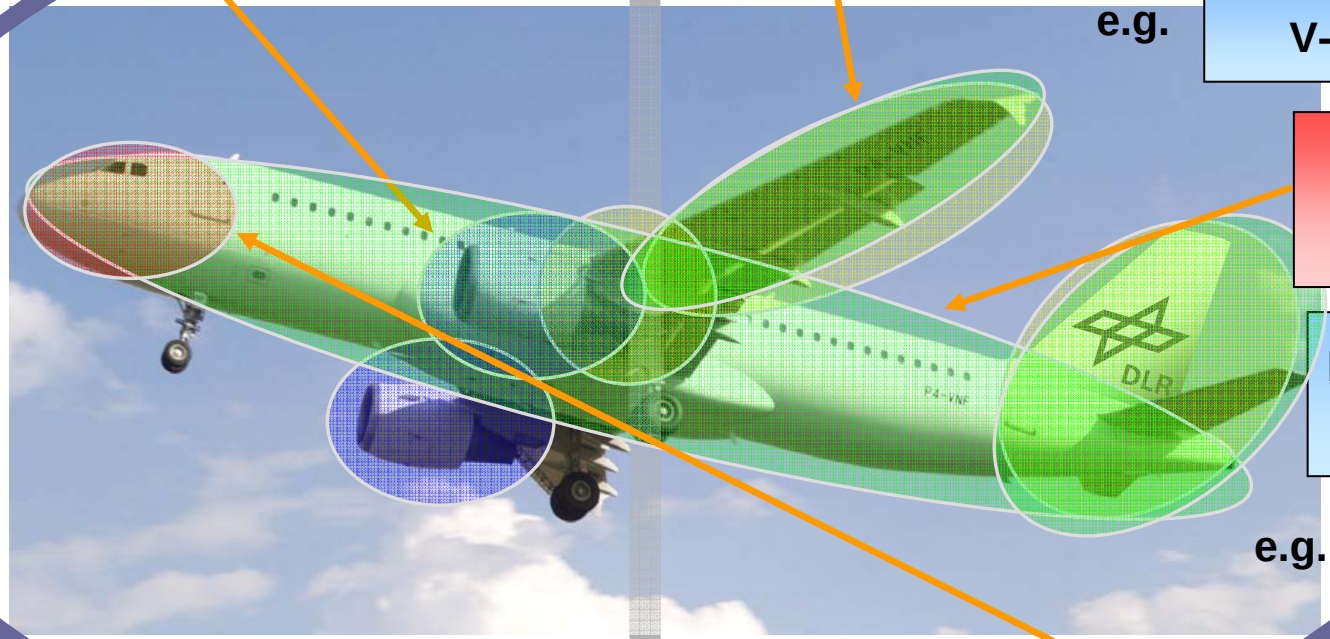
Emission Reduction

Direct Measure

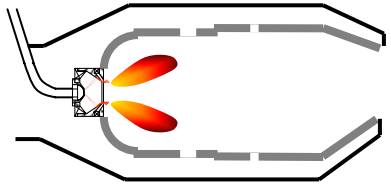
- Engine Optimisation
- Recuperator
- Intercooler
- Geared Fan
- Bleedless Compressor
- Staged Combustion

Indirect Measure

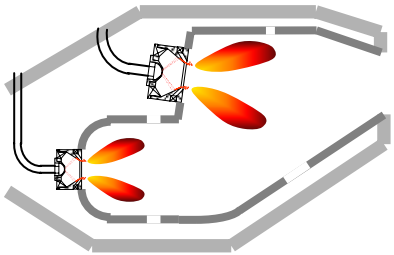
- Drag Reduction
- Optimized Engine Installation
- Hybrid Laminar Flow
- e.g. V-Tail
- Weight Reduction
- New Material CFRP, Glare
- Load Control
- e.g.
- Optimized Flight Procedure
- e.g. Single European Sky



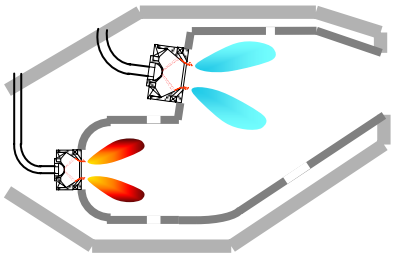
Development Trends for Low Emission Combustors



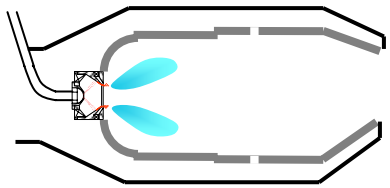
Conventional single annular combustor; burners with diffusion flames



Axially staged combustor;
conventional burners with diffusion flames



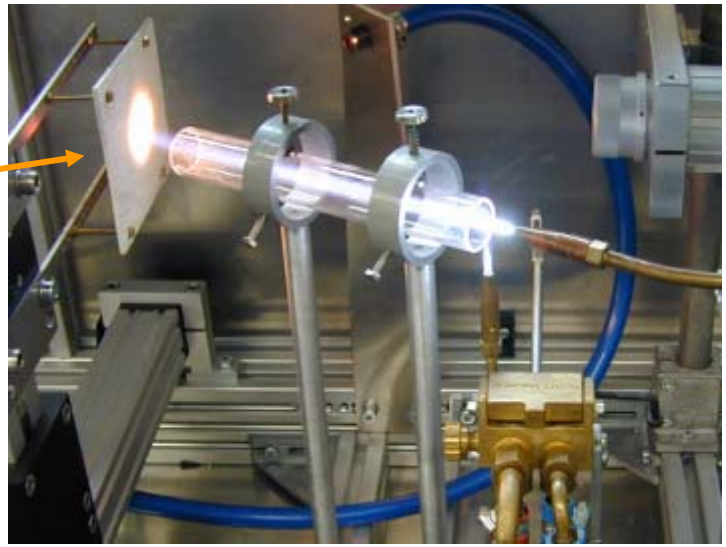
Axially staged combustor;
lean burners in main stage

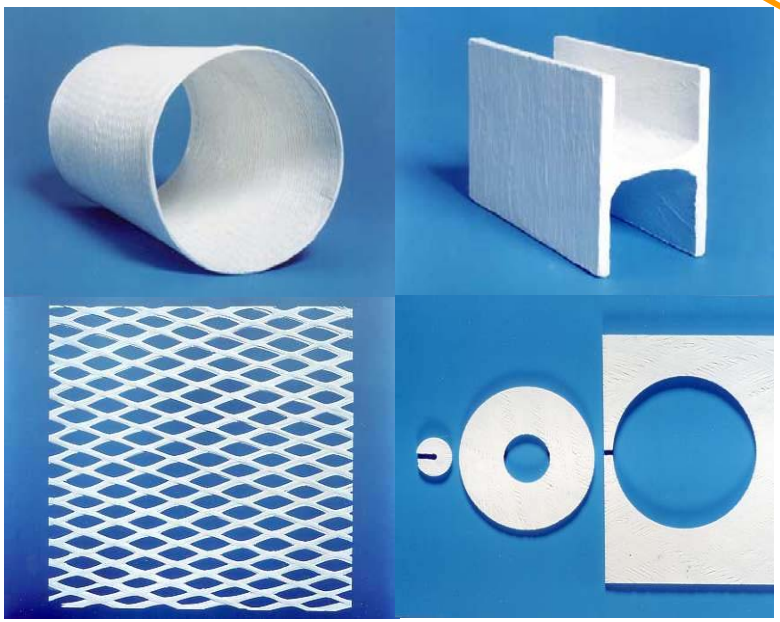


Single annular combustor;
lean burners and internal pilot flames

New Material WHIPOX™ (Wound highly porous oxide composite) for Combustor Walls

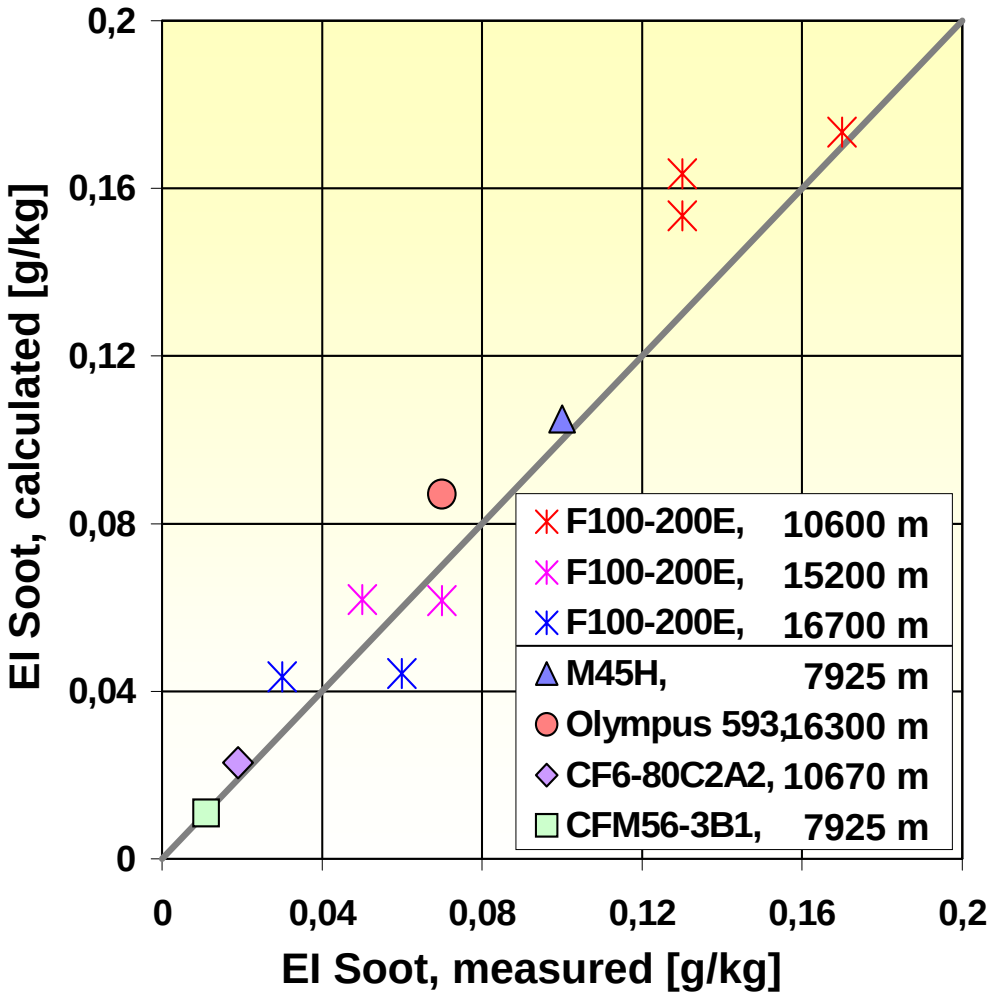
- Non-refractory failure
- Inherent oxidation resistant
- Thermal shock resistant
- Moldable and machinable





Validation of Simulation Tools

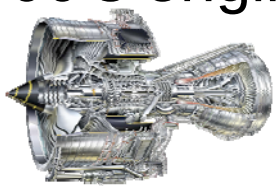
DLR Falcon behind
Lufthansa Airbus A310



In-Flight Measurement of Engine Emissions

Potential for Emission Reduction

2000's engine



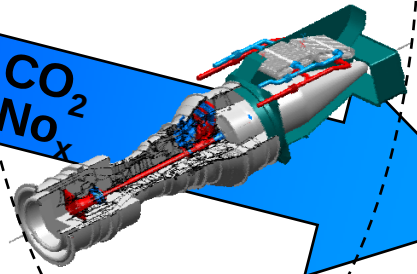
Datum
CO_2 & NOx

ANTLE

-12% CO_2
- 60% NO_x

EEFAE
On going programme

-20% CO_2

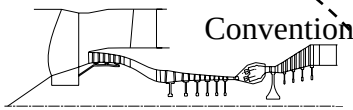


-20% CO_2
-80% NO_x

CLEAN

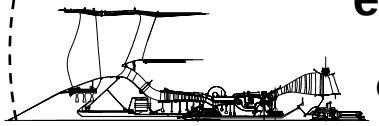
-20% CO_2

VITAL
On going programme

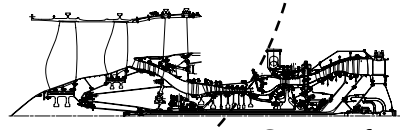


Conventional fan

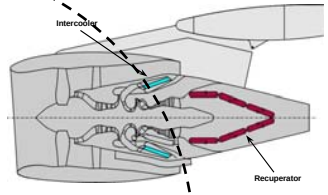
mainly from propulsive efficiency



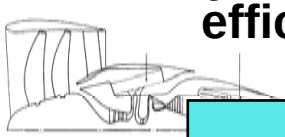
Geared fan



Contra fan



mainly from thermal efficiency



NEWAC
On going programme

Technology Trends

1698 1783 1804 1886 1903 2005

Paradigm Shift

From

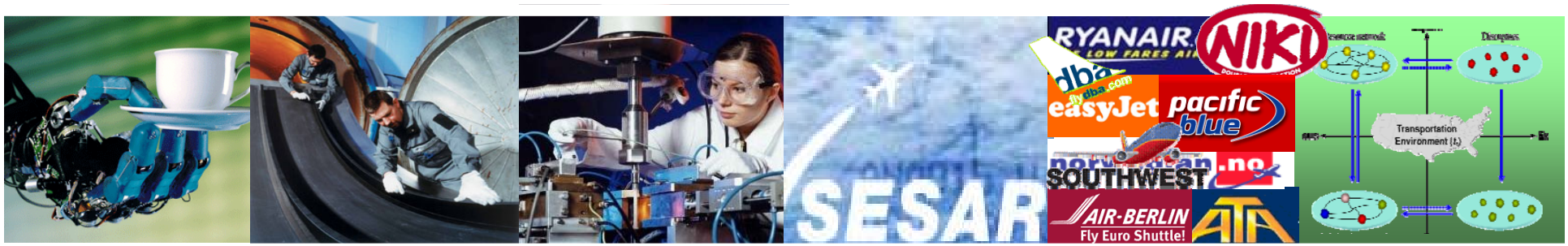
→ **Further, Faster, Higher**

To

→ **Cheaper, Leaner, Greener**

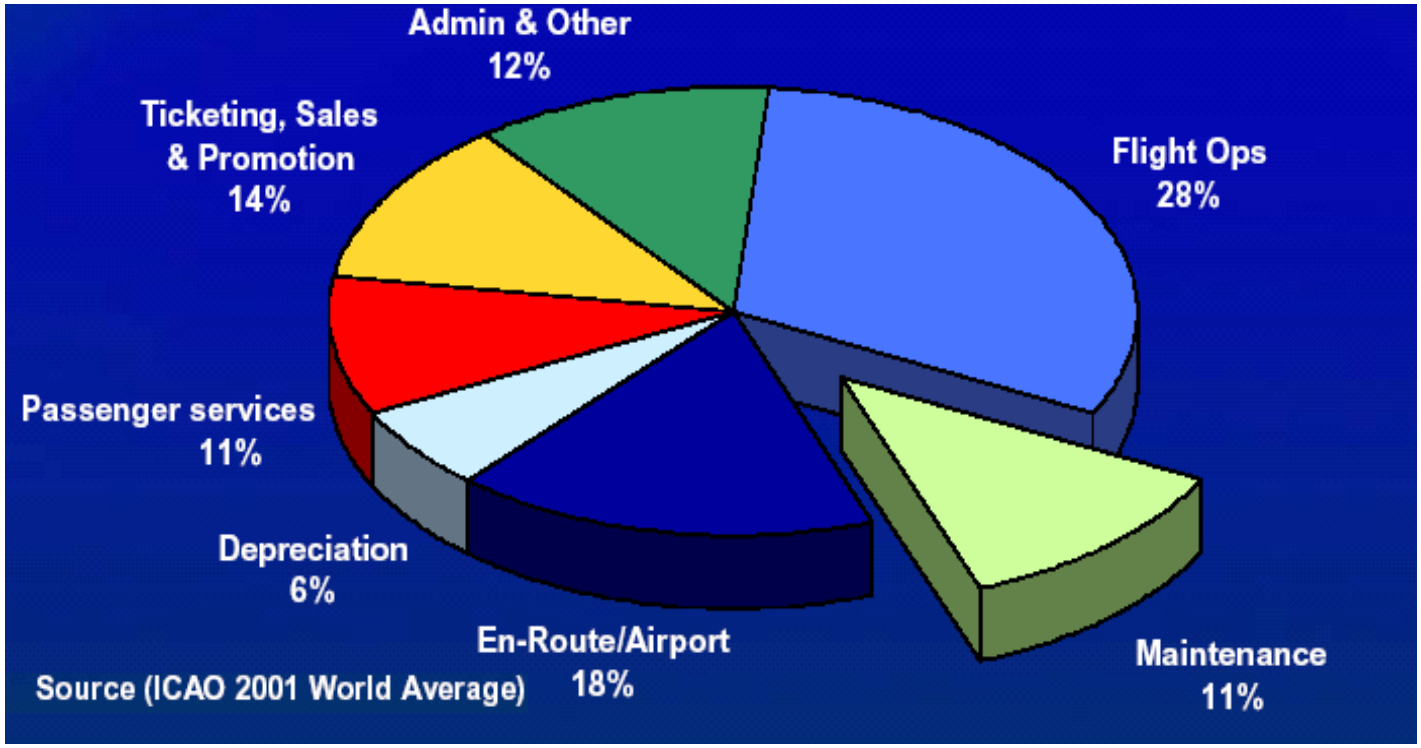
Options for Cheaper, Leaner, Greener

- More efficient, e.g. through:
  - Automation
  - New materials
  - New processes
  - Improved operation
  - Adjustable Standards (Level of Service)
  - Integrated system (System of Sytems/Holistic Approach)



Example “Automation”: Structural Health Monitoring

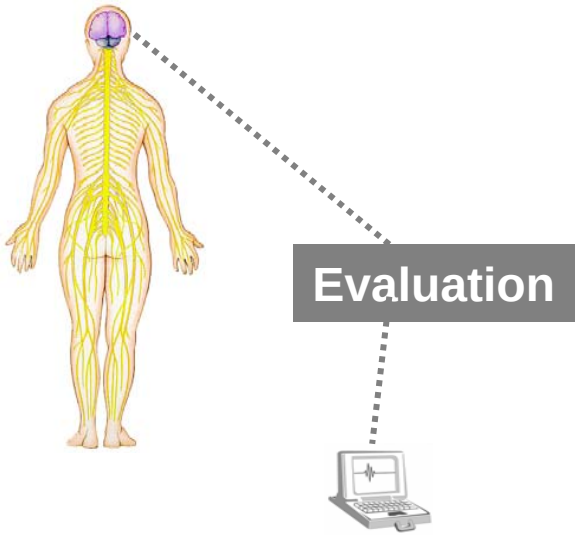
Direct Operating Cost Breakdown



Source: ICAO, Airbus

Example “Automation”: Structural Health Monitoring

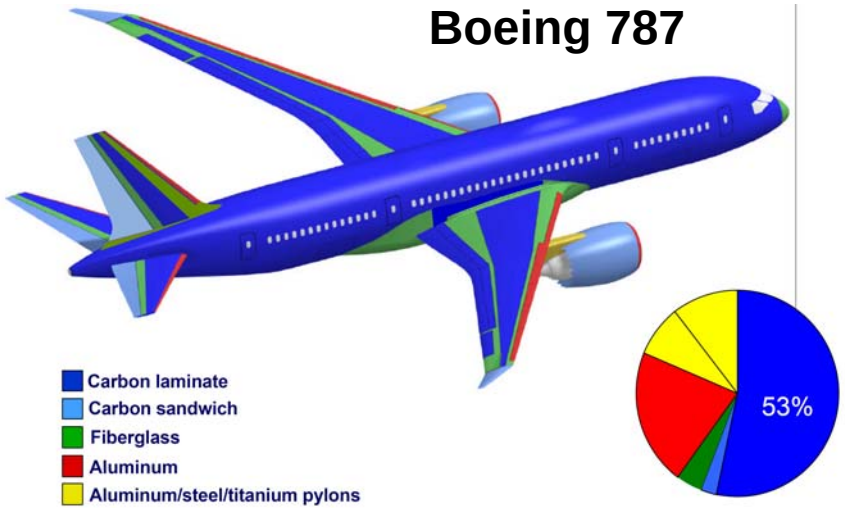
- Human nerve system:
  - The brain detects intensity and location of pain and judges when to go to the doctor.

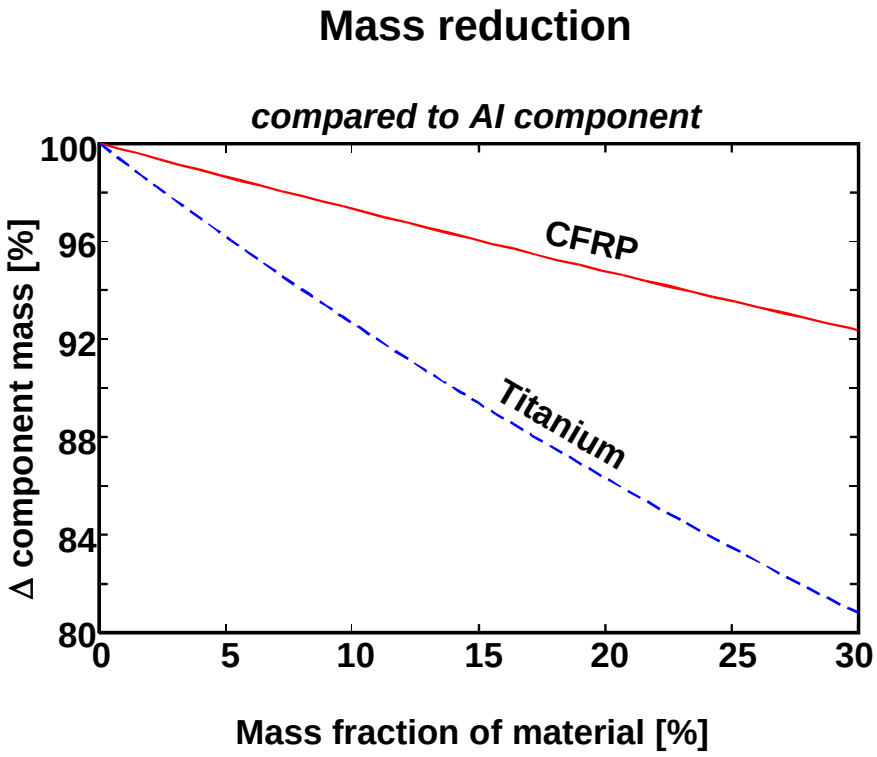


- SHM system:
  - The SHM System checks the structure (diagnosis) and evaluates the follow up actions for maintenance (prognosis).

Source: ICAO, Airbus

Example “New Materials”: CFK/Titanium

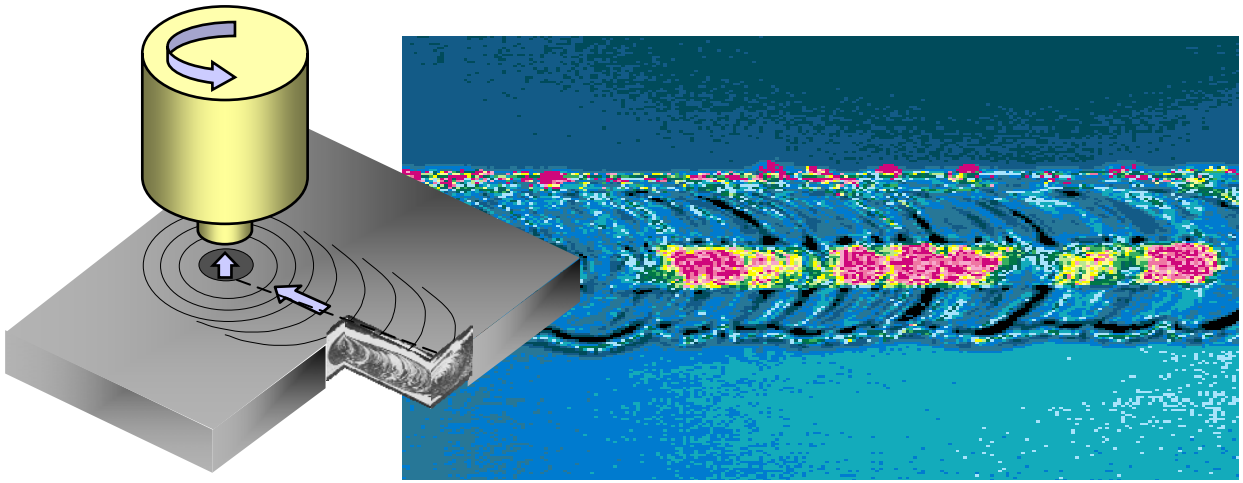




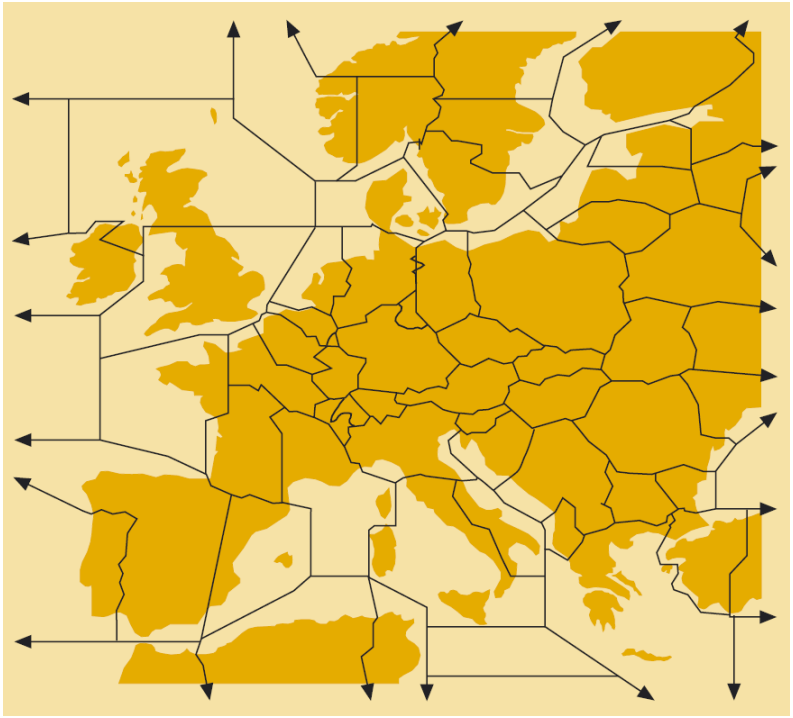
Source: Boeing, TU Braunschweig

Example “New Processes”: Friction Stir Welding

- Joining through frictional heat without reaching the melting point
- Advantages:
  - Good mechanical properties in the as welded condition (no material softening)
  - Easily automated on simple milling machines: low set-up costs
  - Minimal thickness under/over-matching, thus reducing the need for expensive machining after welding



Example “Improved Operation”: Single European Sky



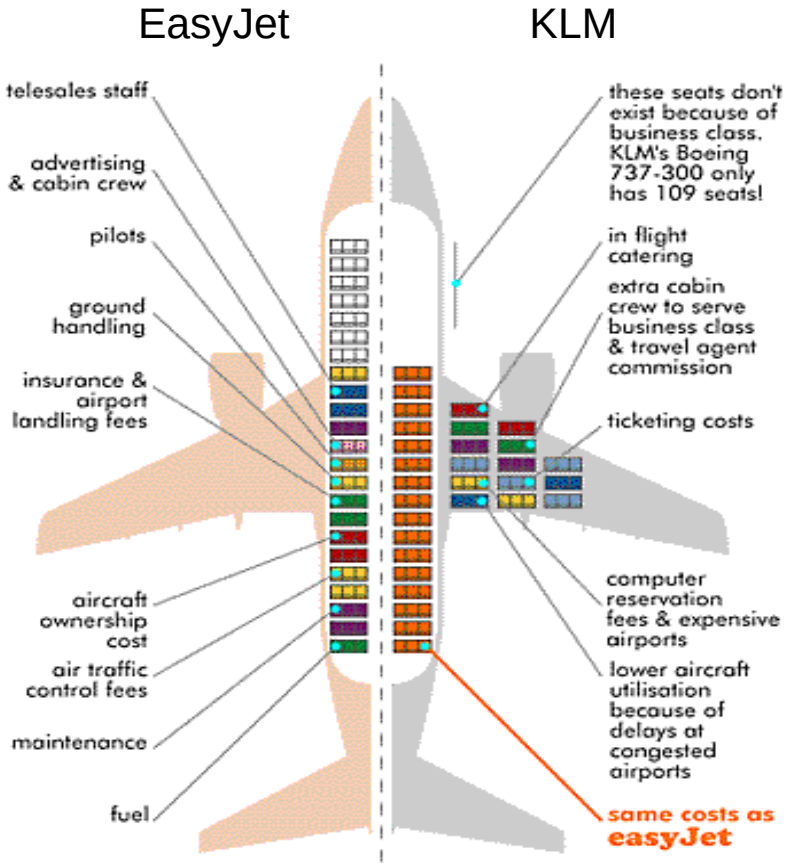
Fragmented European Airspace

	Europe	USA
Air Space (million km²)	10,5	9,8
ATC Service Provider (civil & mil.)	47	1
Centers	58	21
Operating Systems	22	1
Programming Language	30	1
Flights (million)	9	18
ATC Cost per Flight (EUR)	742	386

SESAR consortium

Source: Lufthansa

Example “Adjustable Standards”: No-Frills Airlines



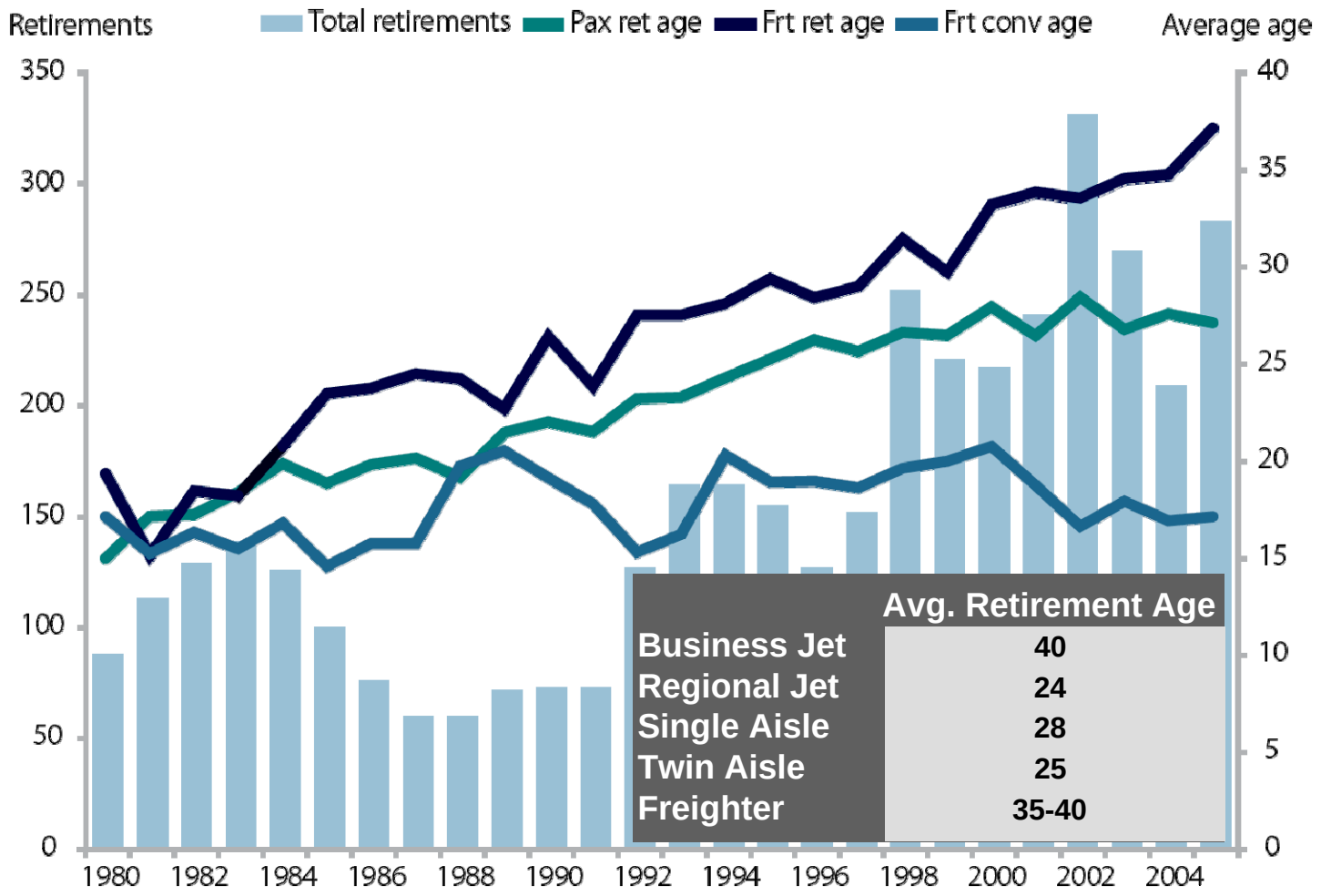
Source: EasyJet Website 2005

Example “Holistic Approach”: Modern Logistics

Future Air Transport Concepts

Source: NLR, Ad de Graaf

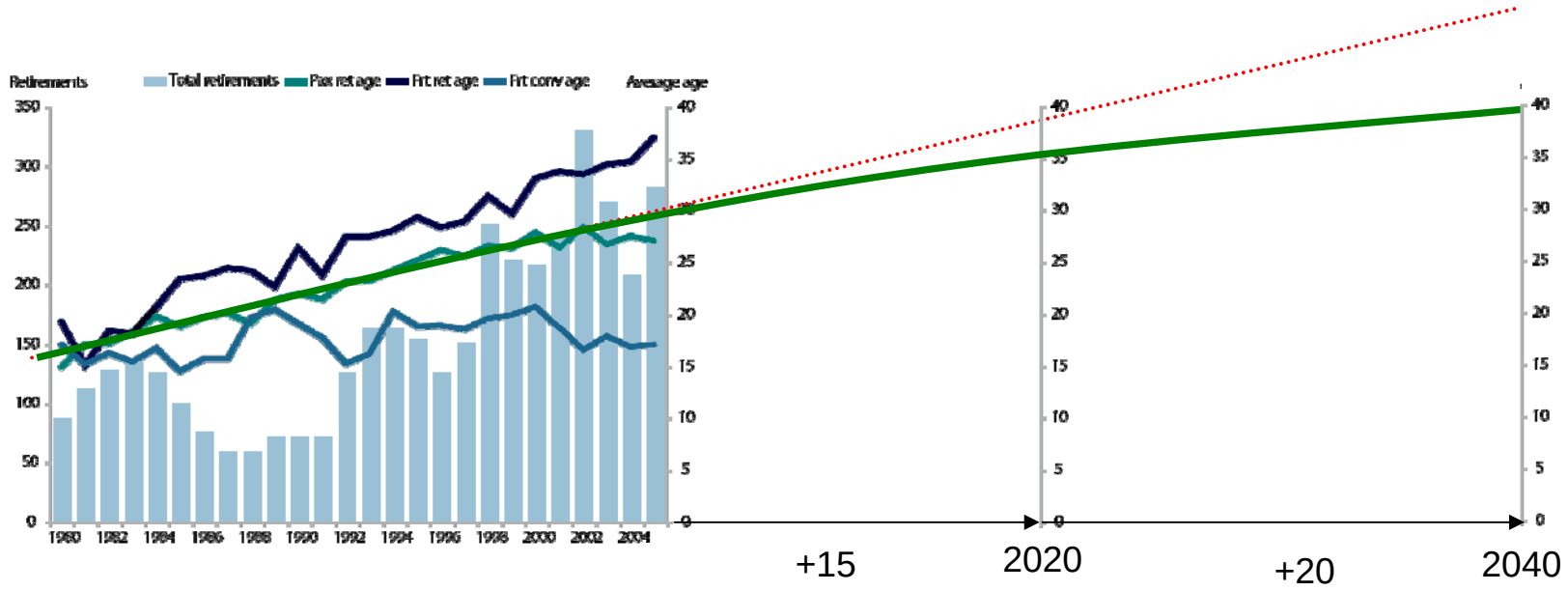
Aircraft Retirement Age (based on current fleet)



	Avg. Retirement Age
Business Jet	40
Regional Jet	24
Single Aisle	28
Twin Aisle	25
Freighter	35-40

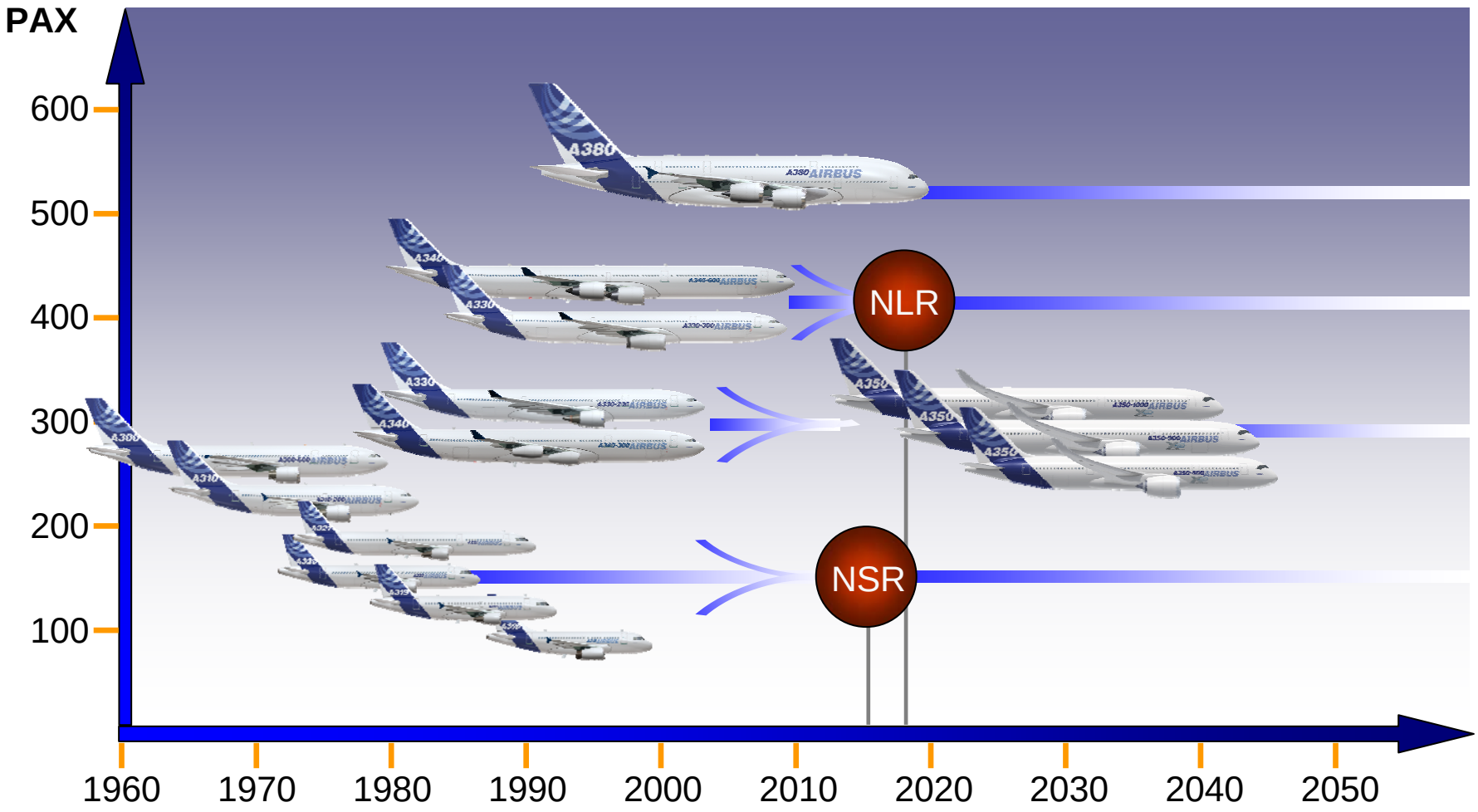
RR Market Outlook 2006

Aircraft Retirement Age (extrapolated)



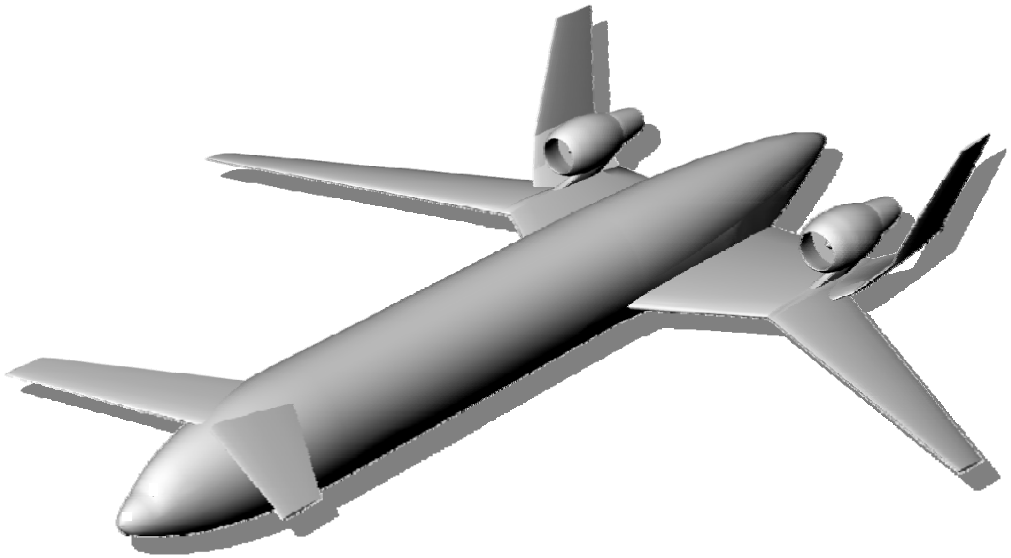
RR Market Outlook 2006

European AC Programs (Windows of Opportunity)



Low-Noise Concepts

- **On-Wing Engine Installation (Noise Shielding: 5-9 dB improvement)**



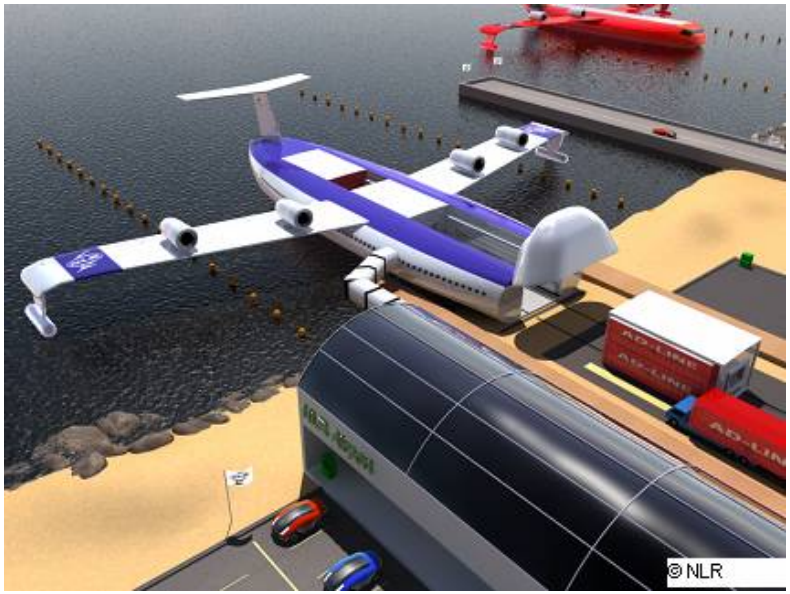
		VFW614	ERJ-145
Take-Off	[EPNdB]	**90,5**	**89,0**
Sideline	[EPNdB]	**92,2**	**94,0**
Approach	[EPNdB]	**97,1**	**98,0**
First Flight	[Year]	**1971**	**1996**

Source: civil-aviation.org

K2020

High Efficiency Cargo Concepts (1)

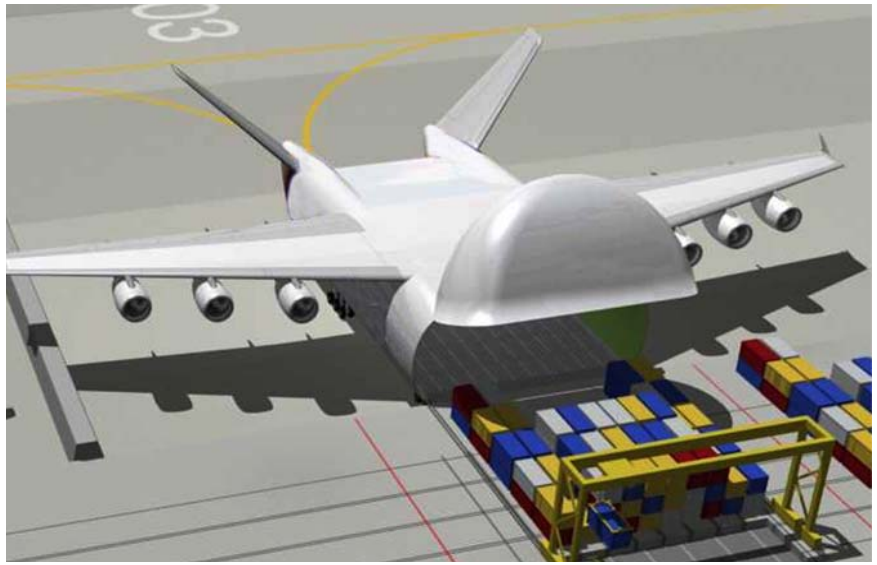
Ground Effect Vehicles



Source: NLR, Ad de Graaf

High Efficiency Cargo Concepts (2)

- **Blended-Wing-Body Freighter/Airliner**



Source: Airbus & NLR, Ad de Graaf

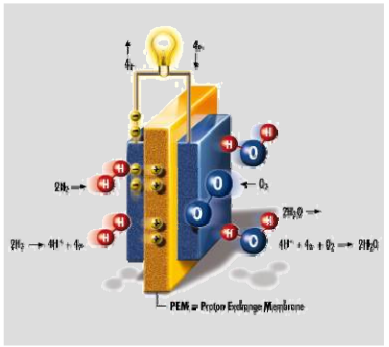
New Airport Concepts

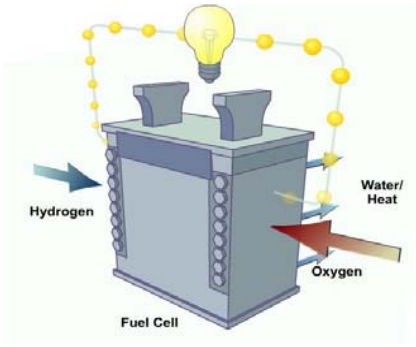
- Off-Shore Airports for 24/7 Operation
- Alternative subterranean Terminals

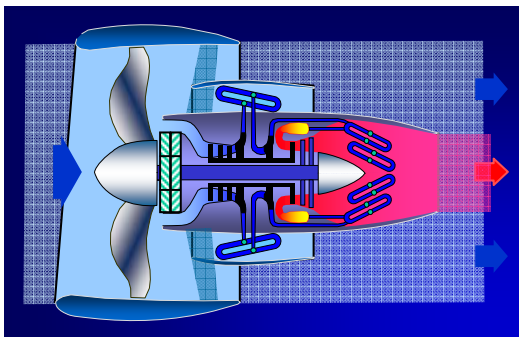
Source: NLR, Ad de Graaf

New Concepts for Propulsion/Energy Supply

- Fuel Cell
- Solar Power
- Distributed Power
- Hydrogen/Bio Fuels
- Geared Fan & Inter Cooler/Recuperator



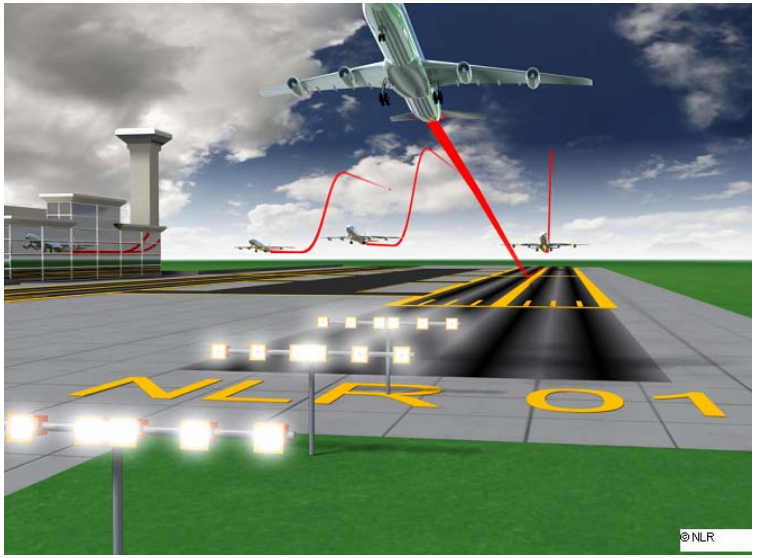




Source: NASA, NLR, Ad de Graaf

New Concepts for Operation

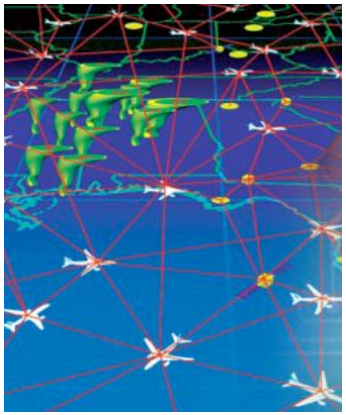
- Aerial Refueling
- Formation Flight
- Paired Approach/paired Departure

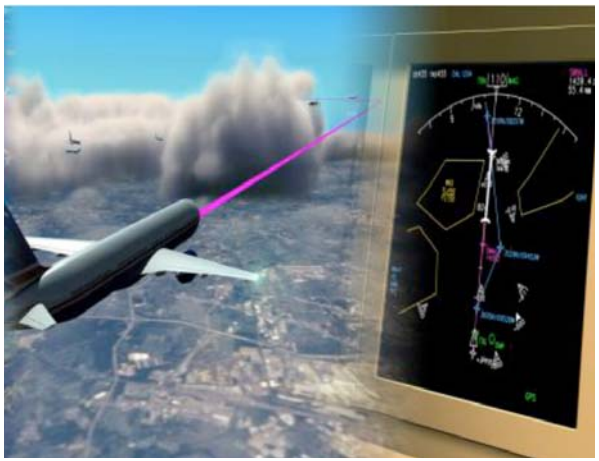
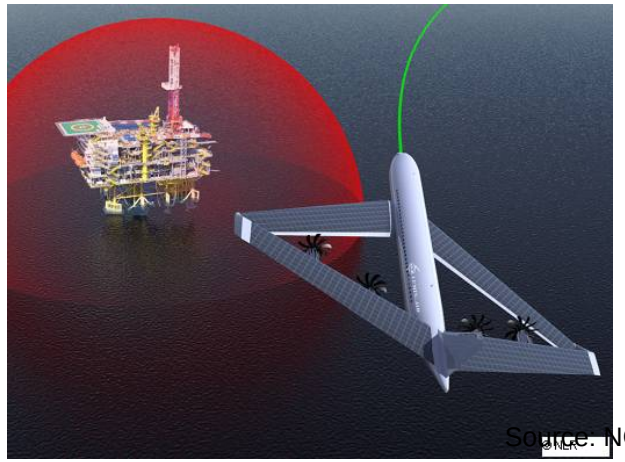


Source: NLR, Ad de Graaf

New Concepts for **highly automated** Operation

- **Unmanned Aerial Vehicle**
- **Data Link**
- **Sense or See & Avoid**

Source: NGATS, NLR, Ad de Graaf

New Concepts for **Personal Air Transport**

- **Tilt-Rotor Concepts**
- **Personal Air Vehicle**

Source: NLR, Ad de Graaf

National Research on Air Transportation

Research establishments and academia doing research on:

- components of air transportation system
- complete air transportation system

DLR Research on Air Transportation

TUHH Technische Universität Hamburg-Harburg

DLR Hamburg

Institute of

Air Transportation Concepts & Technology Assessment

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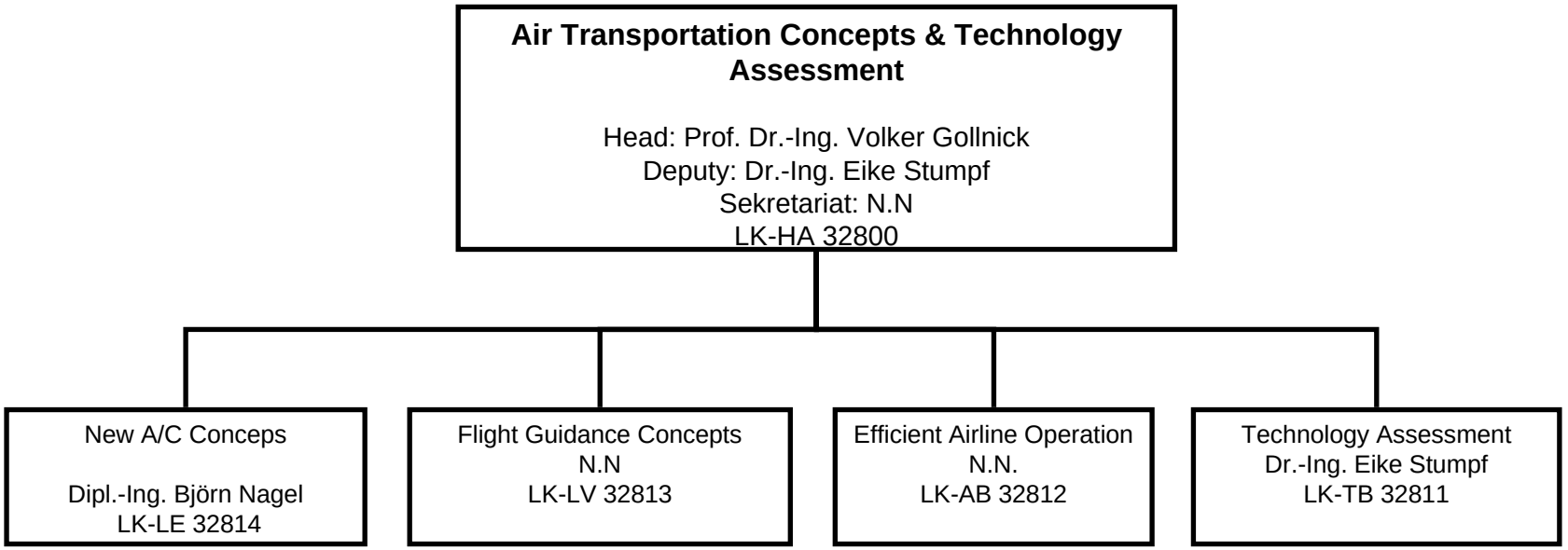
D-21073 Hamburg

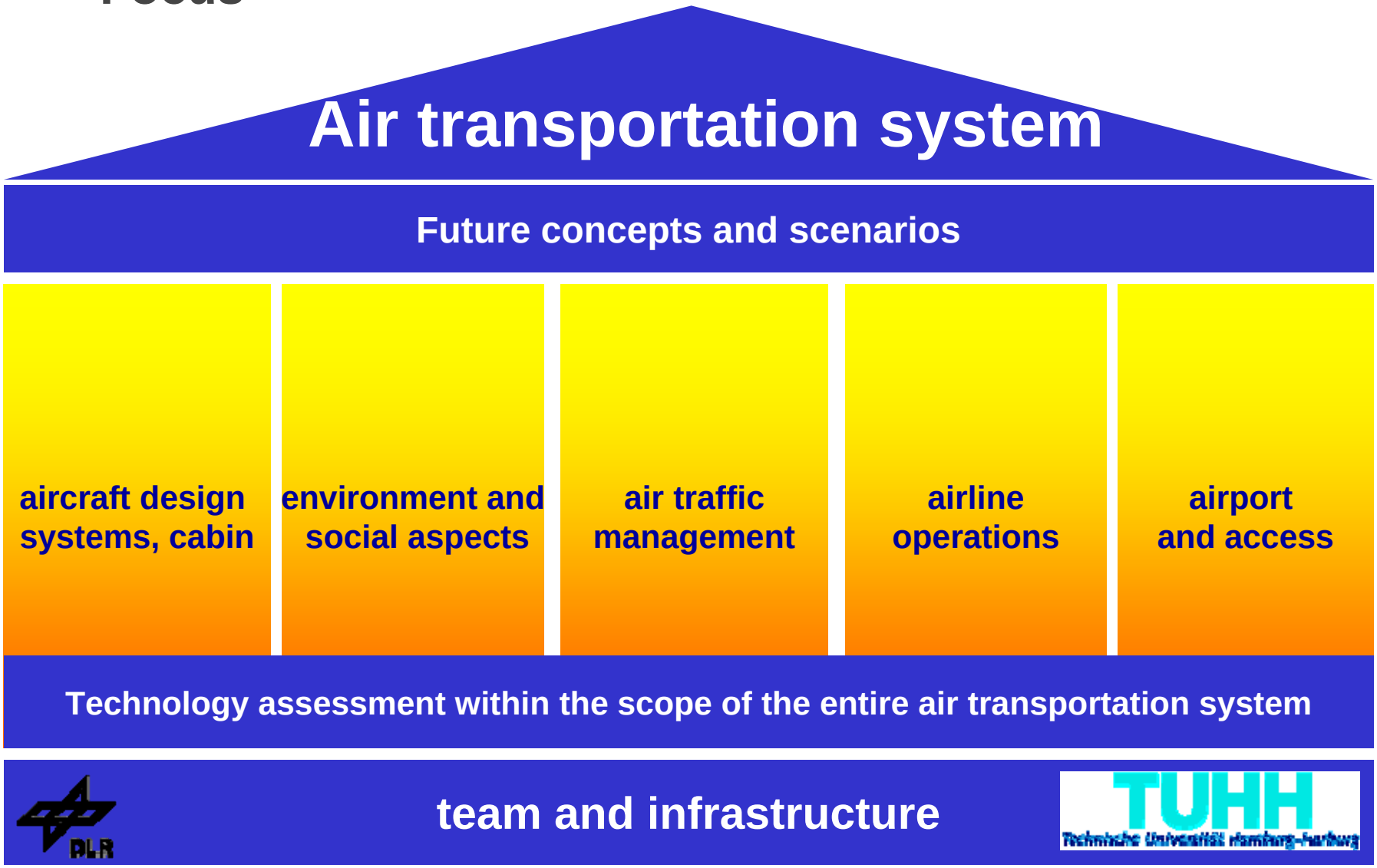
Mission

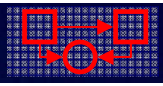
Development/design and assessment of new aircraft concepts, airport infrastructures, air traffic technologies, and aircraft operations

within the scope of the entire air transportation system



Focus


Air transportation system
Future concepts and scenarios
aircraft design systems, cabin
environment and social aspects
air traffic management
airline operations
airport and access
Technology assessment within the scope of the entire air transportation system
team and infrastructure
DLR
TUHH
Technische Universität Hamburg-Harburg



Research Areas

- 3 Main Areas of Research:
  - Development of an **integrated modelling- and simulation system** to demonstrate the entire air transport process inlcuding the capability to zoom into detailed aspects, e.g. aircraft/airport interface, subsystem performances and interactions within an aircraft in flight
  - Development of **future air transportation concepts** addressing
    - new aircraft concepts / configurations
    - air transport processes
    - environemental, social and competitive scenarios
  - Development of **methods and assessment of new technologies** in the overall context of air transport regarding, e.g.
    - techn. performances and limitations,
    - economical benefit for manufacturer, airliner, ATC
    - ecological value

DLR Technology Assessment Process

- Technical Technology Assessment
  - Viability/Feasability
  - Functionality
  - Potential

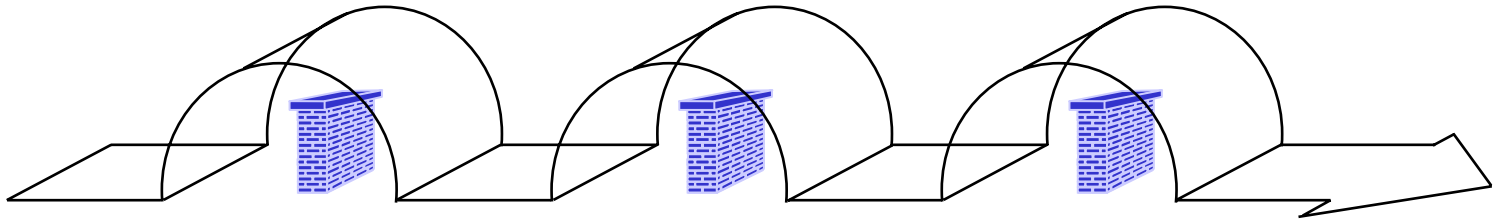
1

- Ecological Technology Assessment
  - Environmental Burden

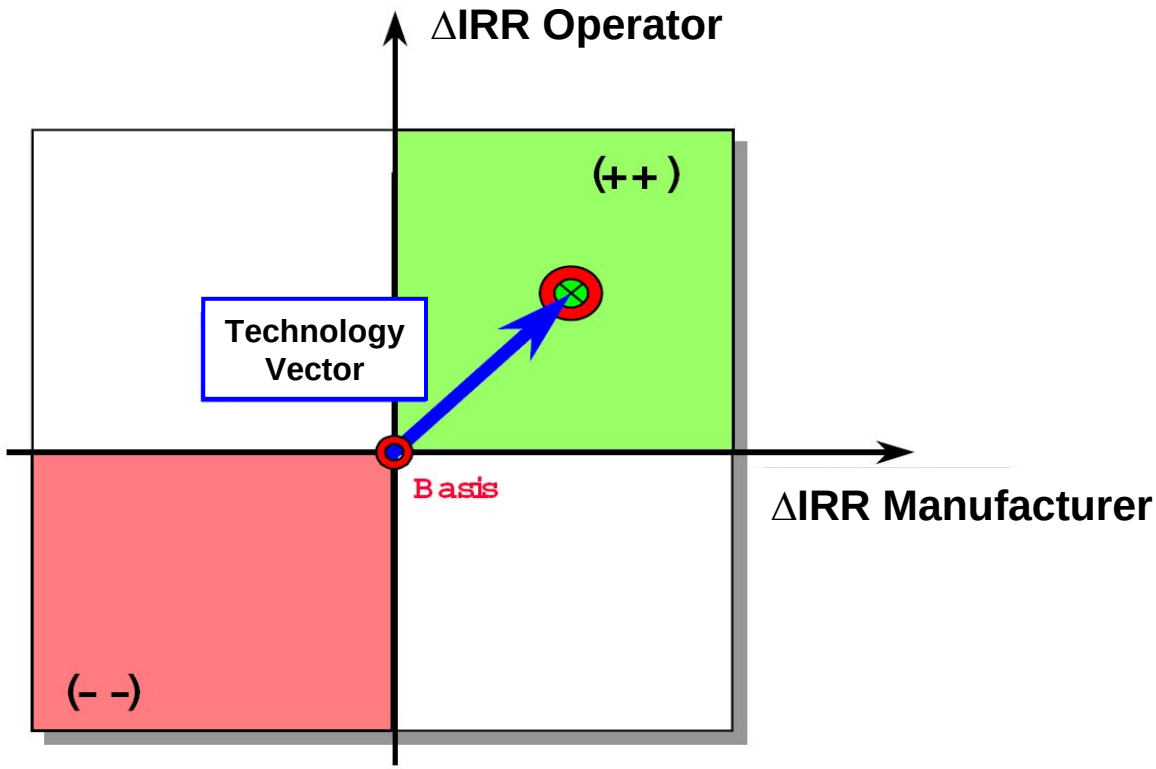
2

- Monetary Technology Assessment
  - Net Present Value
  - Internal Rate of Return

3

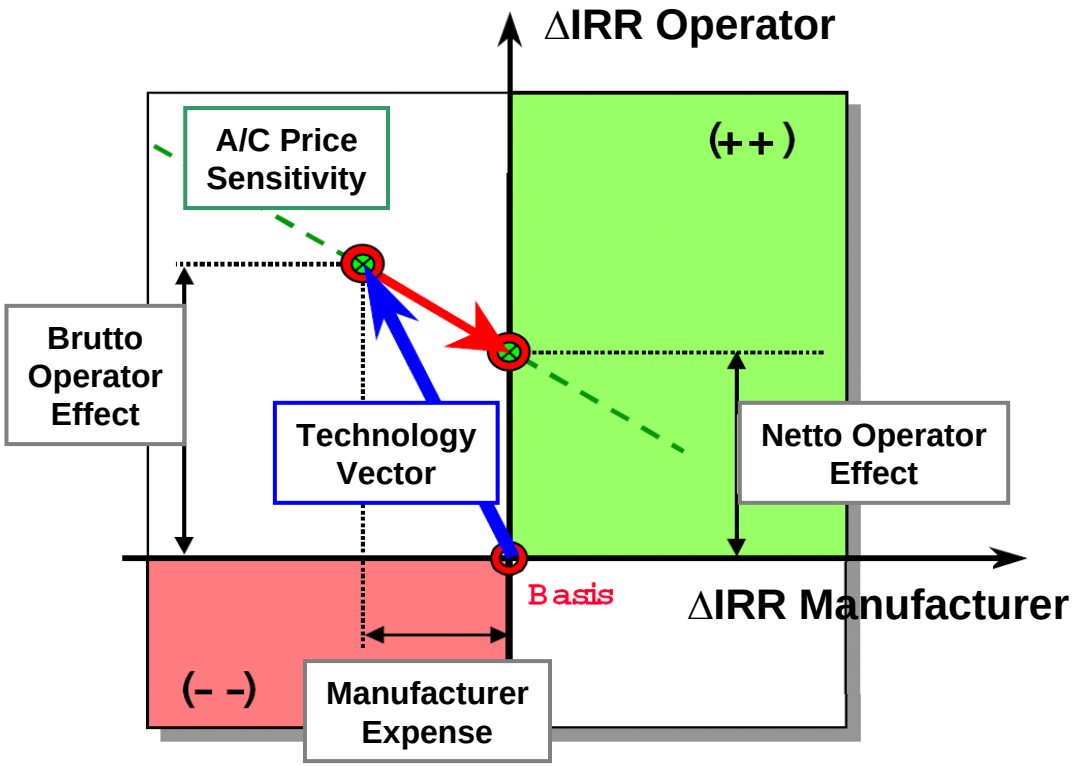


Monetary Technology Assessment (Airbus Method)



Source: Airbus, Hans Schnieder, DGLR

Monetary Technology Assessment (Airbus Method)



Source: Airbus, Hans Schnieder, DGLR

Summary

- Due to tripling capacity the air transportation will gain significant impact on climate
- Future public acceptance of air transportation is dependent on noise and emission levels
- Promising technologies for noise and emission reduction have been identified
- Prompt action and holistic approach is mandatory for future R&D
- With its wide range of expertise DLR is ready to contribute to the future air transportation system

Questions